Residential Sector Climate Change Foundation Paper

National Climate Change Secretariat
Buildings Table

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Executive Summary

The Buildings Table's mandate is to develop, analyse and propose options to reduce greenhouse gas (GHG)emissions in the residential sector. The options presented to the Climate Change Secretariat in May, 1999 will be rolled into a National Climate Change Strategy, along with those developed by 13 other tables, to reduce GHG emissions to 6% below 1990 levels by the years 2008-2012.

This paper attempts to provide the members of the Buildings Table with a comprehensive profile of the residential sector, an overview of the market barriers, drivers, the regulatory environment and decision-makers, and a synthesis of information on relevant technological and program and policy options as a starting point for the Table's deliberations over the fall and winter of 1998/1999.

The Table has defined the scope of the residential sector, for the purposes of this work, to include design, construction, and operation of low-, mid-, and high-rise residential buildings; development issues such as density and zoning (with links to the Municipalities Table); use of "on-site" or "plug-in" renewable technology and micro/cluster energy supply systems (with links to the Technology Table); appliances and plug-loads (i.e., energy-using consumer products); embodied energy of construction materials; construction waste (with links to Municipalities Table); and indoor air quality insofar as it affects the energy-using ventilation requirements.

Carbon dioxide (CO2) makes up over 80% of GHG emissions, as it is almost exclusively a by-product of energy use. For these reasons, much of the Residential Sector Foundation Paper focuses on the potential for reductions in energy use. However, it should be noted that reductions in energy use do not necessarily lead to reductions in GHG emissions. For example, where electricity is generated by hydro, reductions in heat loss from appliances in a home heated by natural gas or oil, or a switch from electric heating to natural gas heating, actually result in more emissions.

The paper proposes a method for accounting for GHG emissions that takes into account all GHG emissions over the entire life cycle of the building, including direct and indirect emissions at the pre-occupancy, occupancy, and post occupancy stages. However, the discussion in the paper is limited to direct emissions, electricity emissions, and emissions in materials in the pre-occupancy and occupancy stages only.

OVERVIEW OF THE RESIDENTIAL SECTOR

Size and Growth Projections

As of 1996, there were a total of about 10.8 million occupied dwellings in the residential stock. At the national level, single detached dwellings continue to be the major dwelling type, about 56% of the total. Attached units and mid-sized apartments less than 5 storeys make up about 29% of the stock.

Only 9% of households live in apartment buildings 5 storeys and over. However, this 9% is clustered in certain large cities in Ontario, Quebec, and British Columbia. In 1996, the high rise apartment stock amounted to about 73 million square metres, or approximately 13% of the total commercial sector floor space.

CMHC projections indicate that roughly 2.5 million new households will be formed between the 1996-2011 period. This will result in about 13.3 million households by 2011, of which 81% exist today. The primary market for energy efficiency improvements is thus in the existing housing stock; however, one fifth that has yet to be built is also a significant opportunity.

Although the growth rates will decline in comparison to the rates experienced during the 1970's and late 1980's (due to the aging of the population), immigration and worker migration is generating strong growth in Ontario, Alberta and British Columbia. The forecasts suggest a slight shift away from single detached to multi-unit households, perhaps a reflection of the fact that household size is declining. Many one-person households will be comprised of older residents.

Age of the Stock

At the national level, more than 20% of the dwellings were built before 1950. While a considerable portion of the stock in this category will have undergone some renovation, experience suggests that much of this renovation activity did not fully incorporate energy efficiency measures. About 50% of existing dwellings were built after 1970; much of this stock has never been upgraded. At the provincial level, not surprisingly, central Canada and the eastern provinces contain a considerable percentage of older stock.

Significant percentages of space heating equipment fall into age brackets where there will be replacement opportunities in the near term. Natural Resources Canada's Energy Use Outlook attributes large energy savings over the next decade to the replacement of older inefficient space heating equipment and appliances with relatively efficient new products. That is, the replacement will occur anyway as the useful life of the equipment comes to an end; however, there is the opportunity to accelerate this cycle.

Ownership

Housing units in Canada are predominately occupied by owners in Canada; 64% own their own homes while 36% rent their dwelling. Breaking these numbers down further, single family dwellings are occupied predominately by owners (86%), while in contrast, about 72% of multi-unit dwellings are rented. Most of the single owned, detached dwellings are located in four provinces: Quebec, Ontario, Alberta, and British Columbia.

Tenure varies by province. The heaviest concentrations of rented dwellings are again in Quebec, Ontario, Alberta, and British Columbia. There are between 61,000 to 86,000 condominium units in Canada, of which it has been estimated that about 21% falls into the category of 4 storeys or more.

Energy Use and GHG Emissions in the Sector

In 1996 the residential sector accounted for about 19% of total secondary or end use energy use in Canada. Energy use increased by 12.3% in comparison to the situation in 1990. Space and water heating together account for about 82% of total energy consumption, of which 62% is for space heating. In 1996, the residential sector was responsible for 17.1% of all secondary energy-related emissions.

Natural Resources Canada data show that overall energy use in the sector is growing, and the energy use per dwelling is also growing, after a decline in the 1990-1995 period. From 1990 to 1996, residential energy use increased at twice the rate of CO2 emissions (12.3% vs. 6.2%). The decline in the CO2 intensity of energy use is due largely to the changes in the fuel mix at both the electricity generation and end-use levels. There was a gradual trend away from oil to natural gas.

The pattern of energy use, by end use, varies somewhat among dwelling types. For example, the share attributed to space heating, in single detached dwellings is approximately 60%. When one moves to mid-and high-rise apartment buildings, the share for space heating ranges from 28% to 60%.

While it should be expected that multi-unit residential buildings consume much less energy than single detached houses on a per floor area basis because of reduced exterior surface area, they are not generally built to high levels of energy efficiency. Row housing is generally more efficient than detached housing on a per floor area basis. However, mid and high-rise multiunit residential buildings consume significantly more energy than single detached houses when the energy consumption of the entire building stock of multiunit residential buildings is compared to that of single detached houses. In new construction, annual energy consumption is comparable between high-rise and single detached buildings. On the other hand, multiunit residential buildings consume less energy than single detached housing on a per occupant basis, due to the smaller floor area per occupant found in this type of housing.

Other factors are contributing to higher energy consumption, offsetting some of the large improvements in the efficiencies of regulated space-heating equipment and appliances over the past decade:

- Regional trends to exposed basement walls or replacement with crawlspaces, leaving more of the house envelope exposed to the elements
- Increasing house size of 1.4% per year
- Increasing window area due to improved window technologies and consumer preference

- Larger water heaters to supply hot tubs and Jacuzzis
- Increased lighting, including landscape lighting and indirect indoor lighting
- Hybrid heating systems to improve comfort and aesthetics, including in-floor radiant heating and the proliferation of gas fireplaces
- Increases in the penetration of electronic equipment and minor appliances

Stakeholders and Decision-makers

It is important to recognise the hierarchy of decision-makers in the sector. A complex mixture of federal, provincial and municipal regulations, taxes and charges, market forces, policy, demographics, and regional economics define the environment in which housing systems are designed, built, purchased, operated, and renovated. Generally, decisions made at higher levels in the stakeholder map will directly affect the potential range of decisions that can be made at lower levels. For example, federal energy efficiency regulations dictate the minimum efficiencies of appliances and equipment imported into Canada and available for selection and installation in new and existing homes. Inefficient products are removed from the marketplace, leaving consumers and builders/renovators the choice of good or better products. Collectively, these incremental improvements generate significant savings over the long term.

Conversely, consumers have few opportunities to make energy efficient choices that have substantial impacts on the individual amount of energy consumed, because of the infrastructure barriers put in place by decision-makers at higher levels. For example, municipal zoning and the planning process directly impact the densities of housing built, and hence the viability of a district heating opportunity for developers, or another alternative energy supply approach.

Characterization of the sector is important, in order to develop customized policy and program instruments that overcome structural barriers to effective implementation. There is a wealth of material available, and the Foundation Paper cannot adequately profile the sector in the preparation time allotted. However, all programs and policies suggested by the table must consider the complex milieu in which the programs or policies may operate; successful implementation depends on a detailed assessment of the areas mentioned above.

OPPORTUNITIES FOR REDUCING RESIDENTIAL SECTOR GHG EMISSIONS

The Foundation Paper presents a range of potential technological and behavioural change approaches for reducing GHG emissions in the residential sector. Briefly, they are:

Reduce dwelling growth rate

- Reduce the need for new dwelling spaces
- Reduce the size of new dwellings
- Improve the use of presently under-utilized spaces (e.g. basements)

- Encourage densification

Reduce initial and recurring embodied energy

Change occupant behaviour (section 3.3 of the paper)

Reduce operating energy - systems approach
- Space conditioning (heating, cooling, ventilation)
- Building envelope
- Windows
- Controls
- Water heating
- Lighting
- Appliances and other equipment (including outdoor equipment)

Promote alternative energy supply systems
- Active solar hot water heaters
- Active and passive solar space heating & cooling
- Photovoltaics
- Wind turbines (building cluster or community level)
- Co-generation and shared energy systems (building cluster or community level)
- Fuel cells

RESIDENTIAL SECTOR POLICY AND PROGRAM EXPERIENCE

Types of Market Interventions

There are four types of market interventions that may be deployed in the residential sector:

- Improve the operation of the market (e.g. licensing and accreditation of service professionals);
- Require individuals and firms to behave in specified ways (e.g. codes and regulations);
- Influence decisions of individuals and firms (e.g., information, incentives);
- Provide goods and services directly (e.g., energy audits, replacement of inefficient equipment)

There are two strategic points at which interventions can influence energy efficiency investments in the residential marketplace:

- At the time of equipment and dwelling turnover (e.g., when equipment has reached the end of its useful life, or when purchasing a dwelling); and,
- Prior to the stock turnover (either the dwelling or equipment, e.g., when energy retrofits are piggy-backed onto renovations, and the purchase of a new appliance

before the end of its useful life.

Key Lessons Learned

Over the past 15 years or so, there have been literally hundreds of initiatives directed at the residential sector energy market. Much has been learned that can help guide the Buildings Table.
Some key lessons are:

- ***Government and other institutional interventions have been critical to ensuring that social welfare goals were achieved***. It is likely that only a small percentage of the energy efficiency achieved to date and, consequently, the GHG emission reductions achieved so far, would have occurred in the absence of market interventions.

- ***There has been a transformation in the residential energy marketplace***. The availability of energy efficient products and services is widespread. Restructuring and deregulation of the energy supply market will affect the way in which energy supplied and marketed.

- ***Market interventions have still fallen short in key sub-markets***. Low-income and tenanted households, both in low- and high-rise structures, and new construction and major renovations are areas where energy efficiency opportunities have not been fully realised.

- ***Market interventions don't always pay off.*** The cost of delivery is sometimes higher than the cost of the energy being displaced. Interventions should foster actions that would not have been undertaken in their absence. "Free riders" dilute the impacts of the programs, and are greater in number when measures with rapid payback periods are promoted and when measures have high current market shares.

- ***Energy audits alone generally result in only limited energy savings.***

- ***Different program approaches fill different niches***.

- ***Marketing strategies and technical/construction support services have a large impact on program participation and services.*** Association with topnotch trade allies is essential.

- ***Financial incentives tend to increase program participation and savings***.

- ***Information campaigns have limited impact***. There is difficulty in moving from energy efficiency awareness to action.

- ***Stop focusing on individuals - instead focus on communities of people with similar values and concerns.*** For significant change, it is necessary to go beyond the individual consumer and start addressing the interest and actions of influencers and decision-makers, such as policy makers, designers, the media, distributors, and others implicated in the structuring of choice and fabrication of possibilities.

POLICY AND PROGRAM (MEASURES) OPTIONS

The paper considers specific policy and program options within the following categories:

1. Dissemination of Information
2. Regulations, Standards, and Codes
3. Financial Mechanisms
4. Utility Sponsored Measures
5. Government Operations
6. Macro Economic Level Measures

Dissemination of Information

Potential information measures include:

- Training for municipal building inspectors
- Training for building supply retailers
- Education of consumers to demand certified renovation contractors
- Building occupant information programs
- Metering of units in multi-unit residential buildings
- Home energy rating systems

Regulations, Standards and Codes

Potential measures include:

- New standards and regulations for equipment not already covered
- Increased stringency of existing regulations
- Provincial adoption of the Model Energy Codes for Houses and Buildings or integration of the energy code standards into existing provincial building codes
- Energy Codes modified/updated to minimize GHG emissions
- New R-2000 or Advanced House type standards
- Energy efficiency guidelines for house retrofits
- Increased enforcement of existing building codes and standards
- Certification of renovation contractors

Financial Mechanisms

Potential measures in this category include:

- Energy pricing
- Rate design (inverted rate structures, load control rates, time-of-use rates, real time pricing)
- Rebates and subsidies
- Tax options (energy taxes, reduced property or sales taxes, accelerated capital cost allowances, etc.)
- Loans (energy performance contracting, lower mortgage rates, PITE calculations for mortgage qualification, location-efficient mortgages, utility supported energy retrofit financing programs, etc.)
- Tradeable Emission Reduction Permits

Utility Sponsored Measures

Potential measures in this category include:

- Energy pricing rate design
- Energy retrofit financing programs
- Green energy
- Performance-based hook-up fees
- Enhanced communications

Government Operations

Government-owned stock can be upgraded though:

- Piggybacking energy retrofits on multi-family upgrades
- Infrastructure renewal program dollars to retrofit multi-unit residential buildings

Macro Economic Level Measures

Some possibilities are:

- Removal of fossil fuel or all energy subsidies
- The use of deregulation and competitive markets to determine the optimal level of energy efficiency and GHG emissions.
- Revenue "recycling" - the use of revenues from a tax to decrease the amount of other distortionary taxes in the economy

1.0 HOW SHOULD THE BUILDINGS TABLE ANALYSE RESIDENTIAL GREENHOUSE GAS EMISSIONS?

1.1 BACKGROUND

At the Kyoto meetings on climate change, Canada committed to reducing greenhouse gases in the years 2008 to 2012, to a level 6% below what occurred in 1990. Meeting this target will require a major effort from every sector of the economy. To facilitate the development of Canada's strategy for achieving this target, the federal government established the National Climate Change Secretariat.

The Secretariat created a number of issue-specific Tables. The "Buildings" Table focuses on commercial, institutional and residential buildings. The Table draws its members from a wide range of backgrounds including government, and the not-for-profit and private sectors. Consistent with the approach taken by other Tables, the Buildings Table began its work by preparing two foundation papers, one for the residential sector and one for the commercial buildings. This report comprises the Foundation Paper for the residential sector.

1.2 OBJECTIVES.

The purpose of this Foundation Paper is to assist members of the Buildings Table in contributing to the development of a national implementation plan addressing climate change. More specifically, the paper provides a base of information from which the Buildings Table may develop and analyse options for reducing greenhouse gas emissions in the residential sector. The paper also serves as a summary for stakeholders and the general public, providing an overview of what is currently known, and of potential future opportunities.

1.3 SCOPE OF THE INQUIRY

This paper addresses technological and policy options related to emissions generated by:

- all low, mid and high rise residential buildings
- energy-using systems and equipment related to lighting, heating, ventilation, and air conditioning, water heating, domestic appliances, and other energy-using consumer products (plug loads, televisions, VCRs, clock radios, portable telephones, satellite dishes, etc.)
- energy supply systems (application of market-ready renewable and alternative energy technology to residential buildings)
- appliances that contain CFCs; and
- embodied energy and energy intensity of building materials.

On-going discussion by members of the Buildings Table has produced some general principles for setting the scope of the Foundation Paper, including the following:

- Consider the impacts of density, building form, and multi-use design.
- Accept some degree of overlap and redundancy with other Issues Tables. Overlap is inevitable and necessary if gaps are to be avoided, and if efficiency is to be enhanced through integration of services and technologies. The National Secretariat can oversee the best fit among the various options.
- Focus on residential buildings as opposed to consumer purchases.
- Focus on energy transformed on-site as opposed to off-site energy supply systems.
- Consider the durability and flexibility of buildings, their recycled content, and the impacts of construction waste.

The paper's intended audience is assumed to be relatively well-informed about climate change and energy consumption issues and terminology. The primary audience is members of the Buildings Table, and the other Tables and groups involved with the Climate Change Secretariat. An important secondary audience is the many Canadians at all levels and locations who are interested in these issues, and who may be involved in creating new policies and making them work.

1.4 AREAS OF OVERLAP THAT WARRANT SPECIAL CONSIDERATION BY THE BUILDINGS TABLE

Connections between the Building Table (residential sector) and the other Tables are presented graphically in Figure 1.1, and described in more detail below:

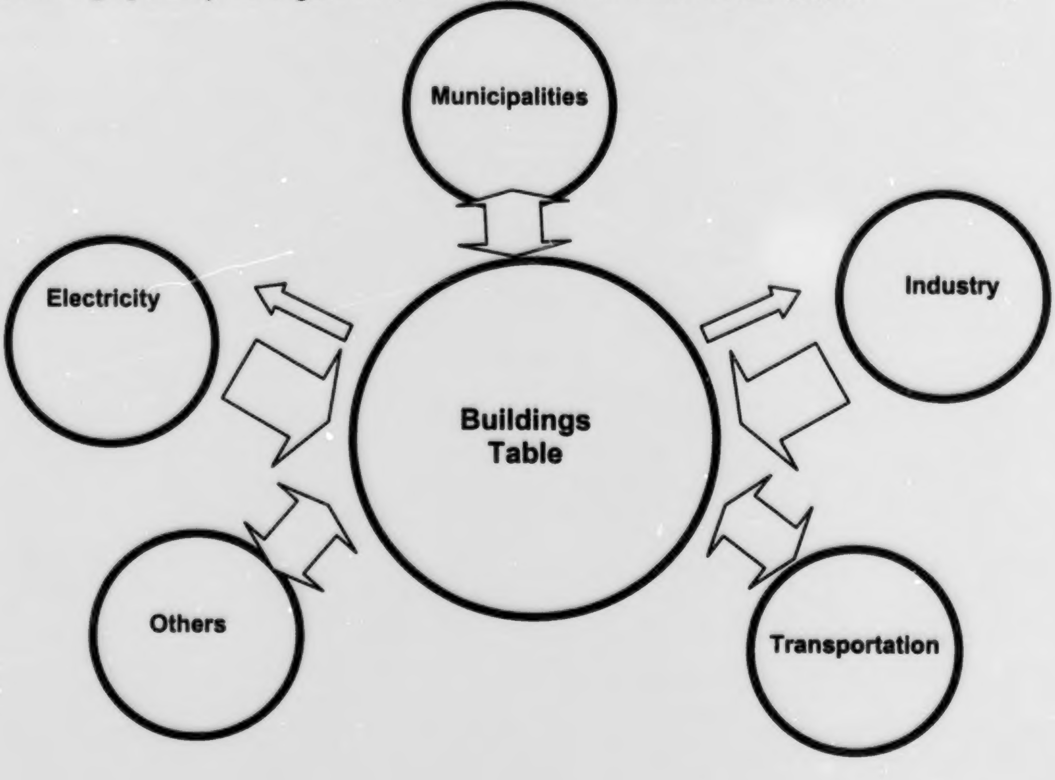


Figure 1.1 Potential Areas of Overlap for the Buildings Table

Interconnections between Tables (or sectors of the economy) can lead to ambiguity about who is responsible. Typically these areas of overlap are ignored, because people are loath to move out of their comfort zone of expertise. Areas of overlap that may warrant special attention by the Buildings table include transportation technologies, municipal services, and electricity supply.

Transportation Technologies: In some communities up to 70% of the transportation system is dedicated to providing residents with access to essential services like school, work, shops, and health care. If "*access to essential services*" is defined as a home service, then transportation is largely an issue for the Residential Foundation Paper. Certainly the Buildings Table is in a strong position to address some of the policies that could ensure provision of access to essential services while simultaneously reducing greenhouse gas emissions. These would include policies to:

- encourage pedestrian and cycling by providing storage facilities and protected pathways in and around residences,
- plan for mixed use developments that combine housing with basic services (corner stores, clinics, day-cares, and so on);
- design housing that could easily adapt to live-work opportunities; and
- plan subdivisions that allow for easy movement of pedestrians and cyclists to basic services and amenities, and to public transit stops.

Municipal Services: Housing developers are becoming involved in localised and clustered utilities that offer households a range of services previously available only through distinct, regulated regional utilities and municipalities. For example, a single housing development may choose to service a number of dwelling units with technologies such as:

- a constructed wet-land for attenuation and remediation of run-off water,
- a 'solar aquatics' type of sewage treatment plant,
- a district heating system;
- a co-generation district energy system,
- a high-rate composting facility and community garden,
- a multi-unit ground source heat pump, or
- a grey water purification and irrigation system.

Such technologies may reduce greenhouse gas emissions; and deserve to be considered by the Climate Change Secretariat. However both the Buildings Table and the Municipalities Table may easily ignore them because they overlap traditional boundaries.

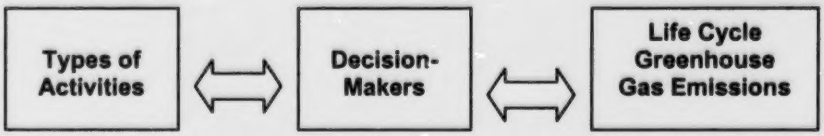
Electricity Supply: As part of Canada's policy on Climate Change, it may be necessary for parts of the electrical generation and transmission system to move towards more "distributed" energy generation. In such a scenario, every new housing development becomes an opportunity to install additional capacity and improve the resiliency of the system. In other words, it may be more cost effective and environmentally beneficial to distribute generation throughout the housing sector, instead of investing in large generating plants with high fixed costs. Housing could incorporate:

- photovoltaic panels, roofs, awnings and walls;
- co-generation plants instead of stand-alone heating systems; and
- wind power generators.

Housing may also need to assist in load management by using controls, storage systems and integrated technologies that can vary usage of electricity by time of day or by season, and thereby help electrical utilities avoid the need for new plants or "dirty" fuels.

1.5 A FRAMEWORK FOR ANALYSING THE RESIDENTIAL BUILDINGS SECTOR

The task of developing and evaluating greenhouse gas reduction opportunities requires a framework that can organise the process of enquiry, and ensure a comprehensive perspective. The graphic below presents such a framework. The analysis involves selecting specific types of activities, decision-makers, and lifecycle stages of the dwelling.



***Example**: Controlling Comfort* — *Homeowner Making a Heating Systems Purchase* — *Direct Emissions From a Gas-Fired Furnace*

Each part of this framework helps to set the scope for the Buildings Table enquiry, as outlined below.

1.5.1 Types of Activities

For purposes of climate change policy, the residential sector can be defined as that group of activities directed towards the provision of home services. Home services include such things as comfort, lighting, and food preparation. A complete breakdown of home services is shown in Table 1.1 below. The level (or quality) of these services may vary from one location to another, and from one time to another. The technologies, materials, and economic relationships used to satisfy the service may also vary. The services themselves, however, remain fairly constant.

The provision of home services is a major stimulus for economic activity. Industries produce the materials and technology. Contractors construct components of buildings and install equipment. Utilities are created to supply energy and resources and to manage wastes. As a direct result of each such activity, energy is transformed, and greenhouse gas emissions may occur.

The focus on services as opposed to buildings can be helpful when identifying options. For example, the most common strategy for providing additional home services is to build a new dwelling, and to include in that dwelling a selection of appliances and furnishings. Another strategy, however, is to provide more services using the existing building stock – by adapting the floor area to accommodate additional people, for example, or by retrofitting dwellings in ways that extend the useful lifetime of the building. Thus the goal is to provide services, not necessarily buildings, and to provide those services using an optimum combination of current technologies, materials and occupant lifestyles.

Table 1.1 Home Services
(in order of decreasing impact on climate change)

- Comfort control
- Transportation or Access to essential services
- Air quality
- Lighting
- Clothes Washing
- Clothes drying
- Refrigeration
- Freezing
- Cooking and Food Preparation
- Outdoor Services
- Personal cleaning and drying
- Audio Visual entertainment
- Communications (including computers and security systems)
- Solid and liquid waste management
- Swimming pools, saunas, hot tubs

Home services are closely connected with services provided by other sectors of the economy. For example, home services are the primary drivers for much industrial activity. Nobody needs energy, materials, or technology per se. Rather our society needs only the services that they provide. If meeting home services in alternative ways reduces the demand for industrial products, then there should be a concomitant reduction in greenhouse gas emissions throughout the industrial sector.

At the same time, it useful to imagine residential services that are delivered by an increasingly integrated urban system. Communities can be designed to function like ecologies, where all waste is food, and where key nutrients are recycled and energy is cascaded through multiple uses. For example, residential buildings can be constructed from industrial waste materials, and they can be designed to capture sunshine and water for use by the commercial sector. Satisfying home services in ways that serve the needs of other sectors is a key principle of sustainable urban design.

1.5.2 Stakeholders and Decision-Makers

All policy is about influencing decision-makers. The decision-makers involved in the residential sector include all the stakeholders involved with the provision of home services. Figure 1.2 provides a useful breakdown of the general categories of stakeholders and decision-makers that may need to be influenced. Each group breaks down further into subcategories. For example, *private companies* includes: developers, designers, home builders, renovation contractors, building inspectors, property managers, and equipment and material suppliers. A detailed map of stakeholders and decision-makers is provided in Chapter 2.

The residential sector includes a wide range of decision-makers. They interact at various times and in various combinations throughout the life cycle of residential buildings, creating a complex decision-making map. Furthermore, these groups may vary with different segments of the housing marketplace. This complexity creates an added challenge for the Buildings Table. Programs and policy options will need to focus on the key groups that influence the decisions.

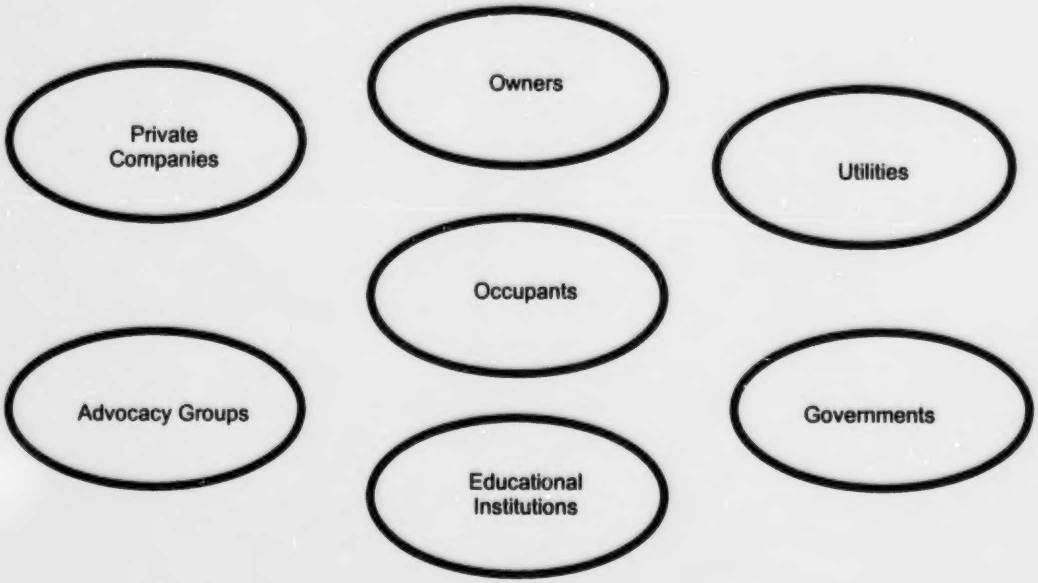


Figure 1.2 Overview of Stakeholders and Influential Groups

1.5.3 Stages in the Lifecycle of a Dwelling

Residential buildings are the most complex, long-lasting consumer products in the marketplace. A single house may have up to 1600 different products, covering over 60 basic commodities (including lumber, steel, plastic, and so on). Some products, like carpets, can be replaced a dozen times over the lifetime of the structure, and may also require periodic maintenance. Other products, like structural members, are rarely or never replaced. For these reasons a clear and robust method is needed to properly account for the flows of energy and materials, and the associated greenhouse gas emissions.

An ideal method for this purpose is Life Cycle Assessment (LCA), as defined in CSA and ISO standards. This method encompasses 3 steps:

1. **Goal-setting and scoping** - Defining the objectives and the target audiences, and setting boundaries on spatial scales, time scales and resource categories and impacts.
2. **Inventory** – Analysing, classifying and categorising all the impacts of buildings at each stage in their life cycle, and then grouping them in appropriate categories so they can be added together; and
3. **Valuation**. – Expressing the impacts in terms that reflect their cost and benefit.

In accordance with the LCA method, greenhouse gas emissions need to be analysed at each stage in the life cycle of the house. Life-cycle stages for buildings include Pre-occupancy, Occupancy, and Post-occupancy.

Each of these stages includes the transformation of materials and energy, and the generation of solid and liquid wastes and air emissions. Flow of energy and material through each life-cycle stage is illustrated in Figure 1.3.

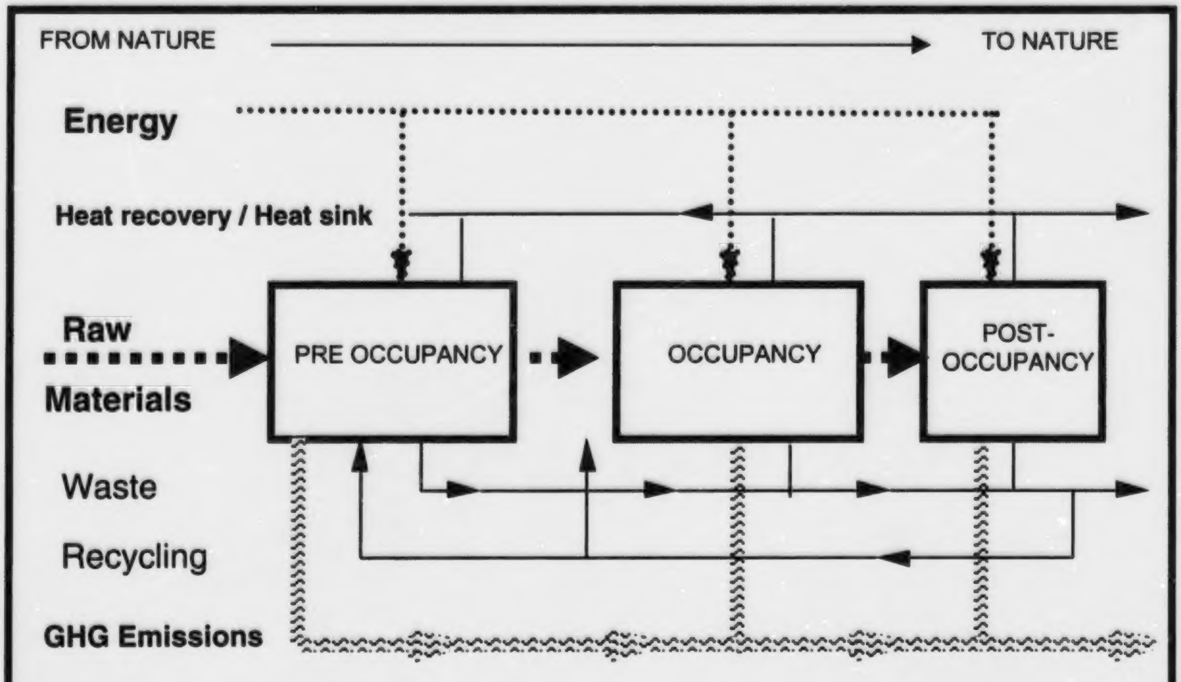


Figure 1.3 Flows of Energy and Materials through the Life Cycle

1.6 CATEGORIES OF GREENHOUSE GAS EMISSIONS

The Residential Sector generates a number of gases that contribute to climate change. Each gas has a different potential for influencing climate change, based upon its molecular structure. Table 1.2 lists the Global Warming Potential of each gas, and the sources for each gas from within the residential sector. Figure 1.4 shows the relative contribution of each gas to Canada's greenhouse gas inventory.

Carbon dioxide constitutes over 80% of greenhouse gas (GHG) emissions, and is almost exclusively a by-product of energy use. For these reasons, much of this paper focuses on the potential for reductions in energy use by the residential sector.

Greenhouse Gas	**Global Warming Potential** (relative to CO^2)	**Typical Residential Sources** (in decreasing order of importance)
Carbon Dioxide (CO_2)	1.0	◆ Natural gas for heating ◆ Natural gas for hot water ◆ Oil for heating ◆ Electricity generation ◆ Etc.
Methane (CH_4)	21	◆ Residential land-clearing and construction waste ◆ Residential household and garden waste in landfill ◆ Sewage treatment plants ◆ Natural gas extraction and processing ◆ Etc.
Perfluorocarbons	HFX23 - 11,700 HFC125 - 2,800 HFX134a - 1,300 HFC152a - 140 CF_4 - 6,500 C_2F_6 - 9,200 SF_6 - 23,900	◆ Manufacture of building insulation ◆ Refrigerators ◆ Etc.

Table 1.2 Greenhouse Gases and Sources of Interest

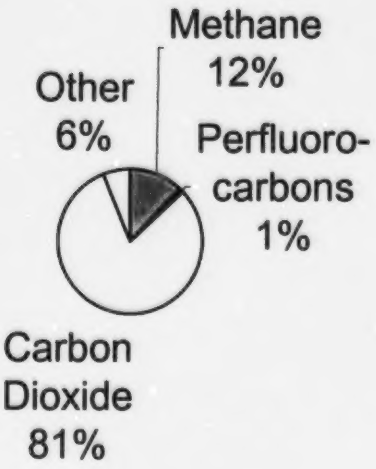


Figure 1.4 Relative Contribution of Greenhouses Gases to Canadian Total, 1995

1.7 LIFE CYCLE ENERGY-RELATED GHG EMISSIONS

Energy-related emissions can be categorised using the energy and mass flow models from the LCA method. From this perspective the operating energy emissions generated on-site during the occupancy stage represent only one of a number of categories that may be of interest to the Buildings Table.

For convenience, the following categories are proposed:

1. **Direct Emissions** –emissions from energy transformed on-site, for purposes of operating the buildings, appliances and household equipment (eg. emissions from natural gas consumed on site).
2. **Indirect Emissions** –all other emissions generated during the occupancy stage, as well as emissions generated during the pre and post occupancy stages

Indirect emissions at each life cycle stage can be further subdivided as shown in Table 1.3 below.

Table 1.3 Sub-Categories of Indirect Energy-Related Emissions in Residential Buildings

EMISSIONS IN ENERGY	♦ **Electricity emissions** (the emissions from the primary energy mix used for electricity generation) ♦ **Full fuel-cycle indirect emissions** (the energy related emissions from extraction, processing, storing, converting and distributing energy consumed on site – including the CO2 and methane vented during mining of oil, gas and coal)
EMISSIONS IN MATERIALS	♦ **Process emissions** (occurring during extraction, processing and fabrication of building materials and products) ♦ **Material Transportation emissions** (from transporting materials to site)
EMISSIONS FROM CONSTRUCTION, RENOVATION AND SERVICE ACTIVITY	♦ **Construction, Landscaping, and Repair Emissions** (from the use of power tools, lawn mowers and heavy equipment on site) ♦ **Worker Transportation Emissions**

A breakdown of all the direct and indirect GHG emissions for three sample new houses in Vancouver, Calgary, and Toronto are presented in Table 1.4. In each case the house is a 140 m^2 single family bungalow with a full concrete basement, using natural gas for space and water heating. The life span for each house is 40 years. Emissions from electrical generation are based on the current primary energy mix for the three regions (BC, Alberta, and Ontario).

As shown in Table 1.4, direct emissions represent a large percentage of the total and definitely warrant special attention by the Buildings Table. However the relative importance of direct emissions varies, depending upon emissions from indirect sources (electricity emissions having the greatest influence on variance) and how many other energy-related emissions are included in the total scope of analysis. If the total includes all the life cycle emissions listed, then direct emissions represent only 48% to 73% of the energy-related greenhouse gases from the three example residential sector houses.

Much of the analysis work completed previously on residential greenhouse gas emissions has been confined to either direct emissions, or to direct emissions combined with electricity emissions. Such a limited scope has tended to overstate the importance of direct emissions.

As residences become more efficient, direct emissions will decrease while the indirect emissions typically increase. The net effect is that indirect emissions will become significantly more important. As Canada heads towards a more aggressive and comprehensive climate change policy, there is increasing justification for a more comprehensive accounting of lifecycle residential emissions.

Some options for expanding the greenhouse gas accounts used by the Buildings Table are discussed below:

1.7.1 Accounting for Electricity Emissions

Electricity emissions refer to the energy-related emissions for electricity consumed during the occupancy stage of the building. Previous analysis of residential sector emissions by NRCan has included both **direct emissions**, and **electricity emissions.** The demand for electricity is created by home services, and thus many opportunities exist for reducing electricity emissions through residential policy. More efficient appliances and lighting are good examples of how residential technology can reduce emissions associated with electricity generation.

The interaction between electricity and other services is sometimes significant, and is discussed in Chapter 3 of this paper. More efficient lighting can increase space heating energy consumption in a fossil-fuel heated home, lowing the net GHG emission reduction effect, or actually increasing greenhouse gas emissions in certain circumstances. Increased use of electricity for space heating (fuel conversion) is another option for residential policy that may lead to a net increase in emissions unless consideration is given to emissions from electricity generation.

Category	Lifecycle Energy (GJ)			GHG Emissions (Tonnes of CO2 equiv.)			% of Total Life Cycle Emissions		
PRE-OCCUPANCY STAGE *(Initial Embodied Energy and Construction Energy)*									
							Van.	Cal.	Tor.
Initial Embodied Energy (Extraction, Transportation of Resources, Fabrication of Commodities, Distribution and Warehousing, Land clearing of site)	271.5			4.350			4.2	1.8	3.1
Construction of Dwelling & Transportation of Workers	2.4			.038			.04	.02	.03
Sub total	***273.9***			***4.388***			***4.24***	***1.82***	***3.13***
OCCUPANCY STAGE *(Operating Energy, Recurring Embodied Energy, and Full Fuel Cycle Energy over 40 year life span)*									
							Van.	Cal.	Tor.
◆ Repair, replacement and renovation activities (Recurring Embodied Energy	183.6			2.940			2.8	1.2	2.1
	Van.	Cal.	Tor.	Van.	Cal.	Tor.			
◆ Direct emissions generated on-site	1512	2368	1936	75.2	118	96.2	72.6	48.1	69.5
◆ Electricity Consumed On Site	1231	1243	1238						
◆ Electricity emissions (primary energy)				6.65	96.0	16.1	6.4	39.1	11.6
◆ Full fuel cycle upstream emissions natural gas	106	166	136	17.3	27.1	22.1	16.7	11.0	16.0
Sub total				***99.2***	***241***	***134***	***95.7***	***98.2***	***97.1***
POST- OCCUPANCY STAGE									
							Van.	Cal.	Tor.
Demolition, Disposal, and Recycling	1.9			.030			***.03***	***.01***	***.02***
TOTAL LIFE CYCLE EMISSIONS									
				Van.	Cal.	Tor.	Van.	Cal.	Tor.
Total for Life Cycle				***104***	***245***	***138***	***100***	***100***	***100***

VAN - VANCOUVER, CAL - CALGARY, TOR - TORONTO

Table 1.4 Breakdown of Life Cycle GHG Emissions for Typical New Gas-heated Single Family Dwellings in Vancouver, Calgary, and Toronto

Advantages of including electricity emissions are:

- **Cost** – Policy development is likely to be more effective if this important category of emissions is included. Least cost opportunities for the residential sector are likely to include some policies for reducing emissions by conserving electricity, or by increasing the efficiency of electricity use.
- **Confidence** – Energy uses in houses interact such that saving energy in one service area may increase energy use in other. Unless electricity emissions are estimated, it is difficult for the Buildings Table to have confidence in the ultimate impact of greenhouse gas reduction policies.
- **Consistency** - Analysing both the direct emissions and the electricity emissions for each opportunity and policy option is consistent with past policy documents from NRCan.

Disadvantages of including electricity emissions are:

- **Regional Variations** – Because the primary mix of fuels (and the associated emissions) varies substantially from one region to another in Canada, analysis becomes more complex. Policies may have to be customised for specific regions, which leads to difficulties in implementation and may require added measures to avoid distorting competition in the marketplace and allocation of wealth.

- **Marginal capacity** – The primary fuel mix in electricity is sometimes very different between the average for a whole region, and what might be used to meet additional needs in one area. In the BC Hydro grid, for example, only 6% of the electricity supply is generated by fossil fuels. However, due to constraints on the existing electrical supply system, any new consumption by houses in the fast-growing Lower Mainland requires greater use of existing fossil fuel-generated electricity, or importing fossil fuel-generated electricity from Alberta or the US. Thus the mix may also vary depending upon whether the housing in question is increasing total electricity demand for the sub-region.

- **Deregulation** – One possible impact of utility deregulation is the creation of a short-term market for electricity throughout North America. As such markets mature, it may be difficult to ascertain exactly what is the primary mix for any particular location.

- **Export Opportunities** – Off-setting use of fossil-fuel consumption in housing by using "clean" electricity may appear to be a good strategy for the residential sector in some parts of Canada. However it may actually be more effective to continue to consume fossil fuels in houses, and instead export the clean Canadian electricity to offset coal and oil-generated electricity in other parts of North America. Without more direction from the Secretariat, it is difficult for the Buildings Table to assess these opportunities, and know the "best use" for clean electricity.

- **Lack of Control and Responsiveness** – Actions by specific utilities, and by the electricity sector as a whole, may cause significant increases or decreases in the greenhouse gas emissions per unit of electricity. This in turn will affect the total performance of the residential sector, despite the fact that the decrease (or increase) in emissions is completely unrelated to any decisions by residential stakeholders. Thus potential is created for a degree of confusion, and frustration, depending upon the size and direction of the change.

1.7.2 Accounting for Full Fuel Cycle Emissions

Full fuel cycle emissions include all the energy-related emissions generated as a by-product of delivering energy to the home. In the case of electricity, this includes

- emissions generated by building and operating the generating plants,
- emissions of methane, CO2, and loss of CO2 sequestration sinks from the construction of hydro-electric generation dams.
- emissions generated by extracting and delivering primary fuels like coal and uranium to the generating plant;
- emissions generated from all the energy that is used up in the process of transforming power for distribution and for use at residential voltages; and,
- emissions generated by the energy lost (as heat) from pushing electricity through the transmission wires.

In the case of natural gas, this includes

- carbon dioxide and volatile organic gases released from the earth as part of extraction,
- leakage of gases from the processing and distribution system, and
- emissions created by using energy to pump and distribute the natural gas through the pipes.

Typically the full fuel cycle energy represents about 10% to 15% additional energy consumption over and above the energy actually delivered. To the extent that energy commodities like electricity and gas are used to provide home services, it may be worthwhile for the Buildings Table to examine options for reducing the full fuel-cycle emissions. Such options could include simply reducing certain types of residential demand, or they could include fuel switching and alternative energy supply systems.

Advantages of including full fuel cycle emissions are:

- **Effectiveness** – Only by examining these emissions is it possible to optimise policy to achieve reductions in greenhouse gas emissions as a whole.

Disadvantages of including electricity emissions are:

- **A scarcity of data** – No source of up-to-date data exists for quickly incorporating such emissions in the accounting.
- **Unnecessary complexity** – for many options the full fuel cycle emissions complicate the analysis without adding information that is likely to affect decision-

making or policy development. In the absence of a sensitivity analysis, it is difficult to justify including the emissions for all options.

1.7.3 Accounting for Emissions in Materials

Advantages of including emissions in materials are:

- **Effectiveness** – these emissions can represent a significant source of emissions, and the majority of the emissions are often generated by only a small category of materials, which simplifies the analysis.

- **Awareness** - Transportation energy is sometimes an important and highly variable factor influencing emissions in materials. Without including this category, no credit will be given for use of local materials in construction and renovation work.

- **New Opportunities** -At the end of the lifetime for a given assembly or building, major credits can be received for those who take the trouble to recover material for reuse and recycling. Only by accounting for emissions in materials is it possible to justify important new policy initiatives that might minimise waste by encouraging adaptive design, reuse of materials, design for disassembly and longevity, and so on.

Disadvantages of including emissions in materials are:

- **Complexity and scarcity of Data** – Designers and decision-makers do not yet have access to appropriate analytical tools and to the up-to-date and comprehensive data bases needed to properly measure reductions in emissions in materials. Accounting for emissions in materials is a potentially complicated task due to the large quantities of data required to differentiate between the many types and brands of specific products used in buildings.

- **Allocation Difficulties** - The emissions associated with the reuse, recycling or disposal of materials are not easy to allocate among different sectors of the economy – do the reductions get credited against the building, or against the new product that is produced from the waste? Demolition emission are especially difficult to estimate due to the highly uncertain nature of future recycling technologies.

1.7.4 Accounting for Emissions in Service Work

Accounting for emissions in construction and service work is difficult to justify at this time because the energy consumed represents only a very small percentage of the total greenhouse gas emissions over the life cycle of a typical dwelling. The majority of emissions in this category relate to the transportation of workers – something that is not easy to influence, and that is likely to be addressed by policies developed for the transportation sector. One exception may be housing located in remote areas, where travel of contractors can represent a substantial energy investment.

1.8 A PROPOSED APPROACH FOR GHG ACCOUNTING BY THE BUILDINGS TABLE

A *full* life cycle assessment approach to residential emissions is not possible, or desirable, given the limited time and data available for this Foundation Paper. Nevertheless, it is still recommended that the Buildings Table adopt the LCA *framework* as a means to clarifying what is included and excluded from the results.

This Foundation Paper follows the LCA framework by:
- Setting the goals and discussing the scope for the analysis in Chapter 1;
- Conducting an inventory of buildings and emissions in Chapters 2; and
- Expressing the impacts of emissions in Chapter 3, by aggregating the emissions from all sources.

A practical approach to accounting for life cycle emissions is described below:
a. Analyse and document separately both the **direct emissions** and the **electricity emissions** for all technologies, behaviours and policy options.
b. Address **emissions in materials** (embodied energy) only to a limited extent, in isolation from other policies for the time being. Analysis will be limited to the pre-occupancy and occupancy stages only, (and no effort given to analysing post occupancy).
c. Avoid analysing **full fuel cycle emissions** for electricity and fossil fuels, until more research is available on how these can best be incorporated into the existing framework of accounting;
d. Avoid analysing the **emissions in services** for the time being.

1.9 ORGANISATION OF THE PAPER

This paper attempts to achieve its purpose through a process of logical inquiry organised around seven questions, each with its own chapter:

1. ***How should the Buildings Table analyse residential greenhouse gas emissions?***
2. ***What is happening in the Residential Sector at present, and how might this change in the near future?***
3. ***What current technologies and lifestyle changes represent opportunities for reducing residential GHG emissions?***
4. ***What have we learned from past initiatives about how to design policies for influencing the residential sector?***
5. ***What potential policies and program options can help to achieve the economic and technical potential?***
6. ***How can the Buildings Table identify the most appropriate selection of policy options?***

1.10 INFORMATION GAPS AND AREAS FOR FURTHER RESEARCH

1. Work with the Analysis and Modelling Table to move towards a consistent method that will allow 'fuller' accounting for residential emissions and policies.
2. Analyse the impact of full fuel cycle emissions on a range of residential options in order to establish the sensitivity of policies to this form of accounting.
3. Prepare a more detailed breakdown of categories of life cycle emissions for a range of housing types and locations, and make conclusions about how to improve policies so as to capture greater reductions.
4. Examine the interface between residential buildings and the transportation, municipalities, and electricity sectors, with a view towards identifying options for a co-ordinated strategy on key policy initiatives

2.0 WHAT IS HAPPENING IN THE RESIDENTIAL SECTOR AT PRESENT, AND HOW MIGHT THIS CHANGE IN THE NEAR FUTURE?

This chapter presents a profile of the residential sector in Canada. Key stakeholders and decision makers in the residential sector are presented. The sector is divided into segments in order to identify possible markets for energy efficiency programs, and to identify which key decision-makers influence those segments. The characteristics of the physical stock and socio-demographics of the sector are then examined. The chapter concludes with a profile of energy use and GHG emissions and a discussion of the factors that have influenced trends in the past and may influence energy use and emissions generation in the future.

2.1 RESIDENTIAL SECTOR STAKEHOLDERS AND DECISION MAKERS

The residential building industry is made up of a large and fragmented group of stakeholders. Interactions between these groups range from collaborative to confrontational. Frequently, however, there is little communication or co-ordination between stakeholders.

The major stakeholders involved in improving energy efficiency in buildings are shown in the side box:

Federal Government
- Natural Resources Canada,
- National Energy Board
- National Research Council /IRC
- PWGSC
- CMHC
- Revenue Canada
- Industry Canada

Provincial Government
- Energy and Envir. Ministries,
- Municipal Affairs and Housing,
- Utilities Commissions,

Municipal Government
- Planning
- Engineering
- Permits

Utility Companies
- Electricity
- Natural Gas
- Oil

Private Companies
- Developers
- Designers (Architects, Engineers)
- Product Manufacturers
- Standards Organizations
- Product Distributors
- Performance Contractors
- Financial Institutions
- Builders
- Home Inspectors
- Building Owners

Building Occupants
- Owners
- Tenants

Home Buyers

Advocacy Groups
- Industry Associations
- Consumer Associations
- Environmental Groups

The number and diversity of these stakeholders has significant implications for formulating policy related to GHG emissions reductions. Each stakeholder has a distinct set of priorities, and authority is diverse, therefore, the task of getting public policy implemented is a long and difficult task[1].

Generally, decisions made at higher levels in this stakeholder map will directly effect the potential range of decisions that can be made at lower levels. For example, standards set by the federal government on minimum energy efficiency requirements can directly affect what buildings are constructed by builders or equipment is produced by manufacturers and hence what buildings and products are available to the consumer. Or municipal zoning bylaws that set housing density determine the viability of district heating systems in communities and hence determine the district heating opportunity for developers.

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[1] Lutzenhiser, L., "Innovations and Organisational Networks", Energy Policy, Vol. 22, No.10, pp.867-876, 1994.

The best policies focus on the needs and capabilities of specific types of decision-makers, as opposed to 'blanket' policies that treat everyone the same. A map of stakeholders and decision-makers provides a useful checklist for improving any policy initiative. In other words, the list can be used to ensure that each policy option has been adapted to best meet the needs and capabilities of each group and sub-group involved with the decisions in question.

2.2 RESIDENTIAL SECTOR SEGMENTS

An essential step in profiling the residential sector as an energy management market is to segment it according to unique tenure, socio-economic and physical building characteristics. This segmentation process is valuable for identifying markets for energy efficiency programs broken down into groups of decision-makers that can be targeted with customised policy instruments.

We propose segmenting the residential sector into the following eight key segments according to dwelling (or attachment) type, tenure (owned versus rented), and income level:

- Low-rise, owner-occupied, mid-to upper-income.
- Low-rise, owner-occupied, low income.
- Tenanted low-to mid-rise buildings
- Tenanted high-rise buildings
- Condominiums
- Assisted housing
- Co-operatives
- First Nations Housing

Table 2.1 identifies the primary energy management decision makers, and the extent to which other stakeholders and decision makers influence their decisions, for each of these segments, As shown, we suggest that government, particularly at the provincial and municipal levels, will continue to play important influencing roles. We also recognise the growing importance of the private home inspectors, primarily in the low-rise segments and the lending community. The potential influence of these decision-makers and influencers will vary between existing buildings versus new construction.

This segmentation process is valuable for identifying which decision-makers can be targeted with customised policy and program instruments. While this characterisation is, of course, subjective, it does highlight the need to consider the residential sector in a more "organic" light, with interactions and communications occurring at various levels and directions. While these segments are valuable for identifying policy target groups, they must be further broken down by building type, age, and region to be useful for evaluating the impact of technological improvements and targeted policies.

Table 2.1 RESIDENTIAL SEGMENTS AND INFLUENCERS

Residential Segments		Primary Decision Makers	Potential Influence of Key Stakeholders								
			Fed. Gov.	Prov Gov.	Mun Gov.	Utilities	Devel. & Builders	Equip. Suppliers	Lenders	Home Inspectors	Retail
1.Low-rise owner occupied, mid-to upper-income.	New	Devel., Builder, Owner	M	H	H	H	H	M	M	L	M
	Existing	Owner	M	M	M	H	H	M	M	H	H
2.Low-rise, owner occupied, low income.	New	Devel., Builder, Owner	H	H	H	H	H	M	H	L	M
	Existing	Owner	H	M	M	H	H	M	H	H	H
3. Tenanted low-to mid-rise.	New	Developer, Designer, Owner	M	H	H	H	H	M	M	L	L
	Existing	Building Owner	M	M	M	H	M	M	H	M	M
4. Tenanted high-rise.	New	Developer, Designer, Owner	M	H	H	H	H	M	M	L	L
	Existing	Building Owner	M	M	M	H	M	M	H	M	L
5. Condominiums	New	Developer, Designer	M	H	H	H	H	M	M	L	L
	Existing	Condo Board	M	M	M	H	M	M	H	M	L
6. Assisted housing	New	Gov. /Non Profit, Designer	H	H	H	L	L	M	L	L	L
	Existing	Gov. /Non Profit	H	H	M	M	L	M	L	L	L
7. Co-Ops	New	Gov. /Non Profit, Designer	M	H	H	L	L	M	M	L	L
	Existing	Co-Op Members	M	H	M	H	M	M	H	L	M
8. First Nations Housing	New	Band, Gov., Builder	H	H	H	L	L	M	M	L	L
	Existing	Band, Gov.	H	M	H	M	M	M	M	L	L

Legend Potential Influence: L – Low M- Medium H- High

▭ - High Potential Influence on Either New or Existing Building Segment

2.3 PROFILE OF THE RESIDENTIAL DWELLING STOCK AND OCCUPANCY

2.3.1 Breakdown by Dwelling Type

As of 1996, there were a total of about 10.8 million occupied dwellings in the residential stock. Figures 2.1 and 2.2 profile, at the national and provincial levels, the distribution of this stock according to type of dwelling.

At the national level, single detached dwellings continue to represent the major dwelling type, about 56% of the total. The category of "Other" represents about 29% of total dwellings; this is a very diversified group which includes row houses, duplexes and mid-sized apartment buildings less than 5 stories.[2]

The category of apartments 5 storeys and over represents about 9% of total households. Together, the Other and Apartment segments represent a significant and largely untapped energy retrofit sub-market. In 1996 the high rise apartment stock amounted to about 73 million square metres, or approximately 13% of the total commercial sector floor space.[3]

Mid-rise and high-rise multi-unit residential buildings (MURBs) represent an important, yet poorly understood, segment of Canada's building stock. Together they represent a large proportion of all households in Canada but are not consistently included in studies of the residential building stock nor the commercial building stock and hence tend to fall between the cracks. Policy analysts, planners, and researchers are hampered in their ability to formulate and support federal policy for this important sector by the current lack of information.

There are approximately 61,000 to 86,000 condominium units in Canada, of which it has been estimated that about 21% of this total falls into the category of 4 storeys or more. Condos can be found in low, mid, and high-rise buildings.

At the provincial level, it's clear that in Quebec, Ontario, B.C. and Alberta the category of Other is proportionally greater than in the remaining provinces. Ontario and Quebec account for about 80% of the apartments over 5 stories category.

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[2] Natural Resources Canada defines the residential sector to include four major types of dwellings and buildings: single detached, single attached, apartments and mobile homes. For this particular definition, the apartment category includes duplexes, townhouses, mid-sized buildings ($\leq$ 4 storeys) and high rise buildings (> 4 storeys). See *Energy Efficiency Trends in Canada 1990 to 1996*, June 1998. CMHC has used a slightly more disaggregated categorisation distinguishing among apartment, duplex, row, semi-detached and single detached.

[3] Marbek Resource Consultants. 1996. Energy Performance Contracting and the Residential Sector, prepared for CMHC, Figure 3.1. The energy efficiency opportunities in certain portions of the apartment markets tend to transcend what we normally consider to be a residential building. In particular, the nature of mechanical systems in mid-to high-rise apartment buildings is similar to other commercial type buildings.

Figure 2.1
Distribution of Dwellings by Type
Canada 1996

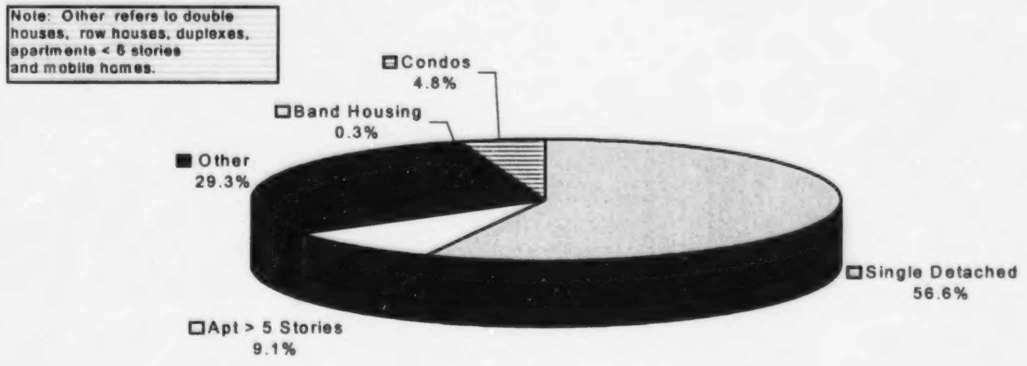
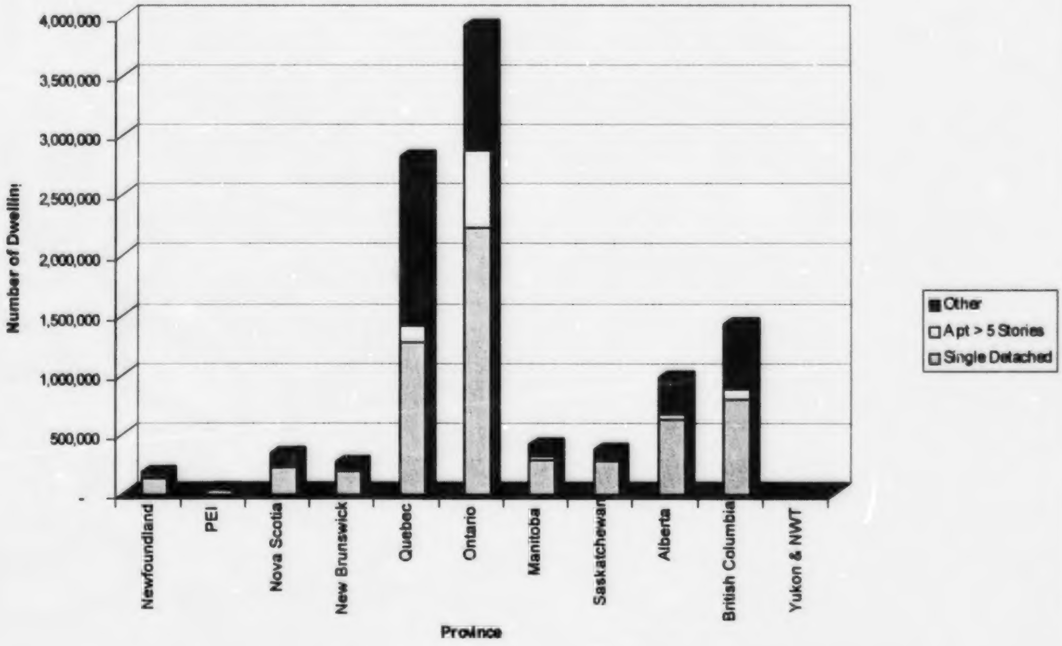


Figure 2.2
Distribution of Dwellings by Type



2.3.2 Breakdown of Dwellings by Ownership

In 1996, the overall break-down between owned and rented dwellings was, respectively, 64% and 36%. Approximately 89% of single detached dwellings are owned, while in contrast, about 72 % of multi-unit dwellings are rented. At the national level, the distribution of owned dwellings with mortgages in 1996 was 52% with active mortgages and 48% without. Figure 2.3 profiles the breakdown of tenure by province. It highlights the significant percentage of rented, multi-unit dwellings in Quebec, Ontario, Alberta and B.C.

The break-down between owned and rented dwellings changes considerably according to household income. The higher the income, the higher the percentage of owned dwellings, as illustrated in Figures 2.4 and 2.5. There are typically many households in one building, often rented.

Figure 2.3
Tenure by Province, 1996

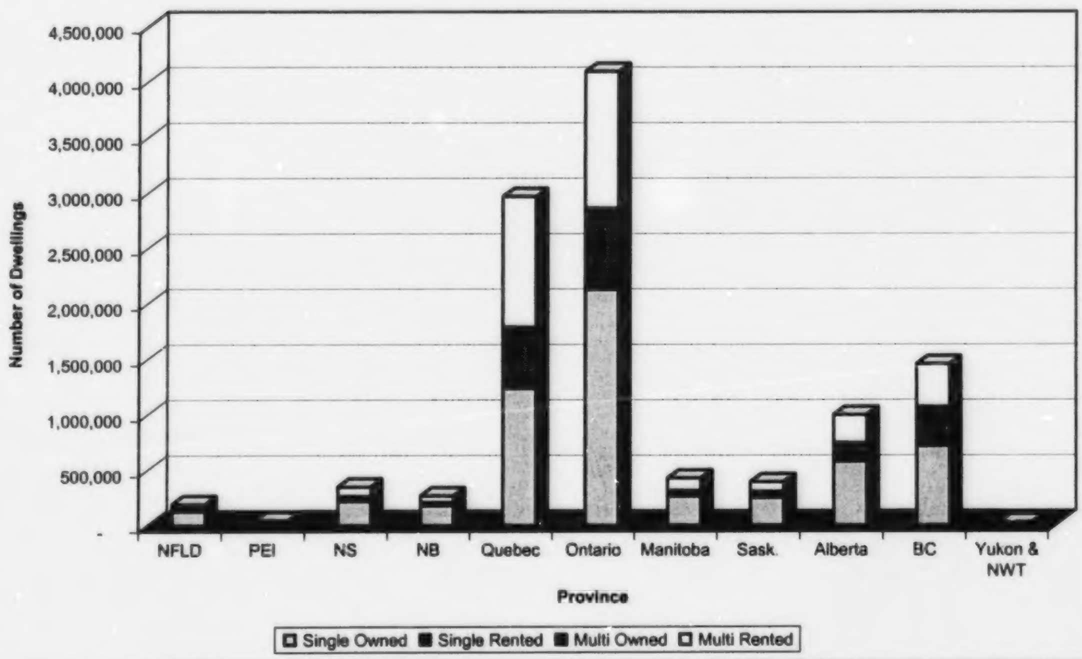


Figure 2.4
Breakdown of Tenure by Income Groups, Canada 1996

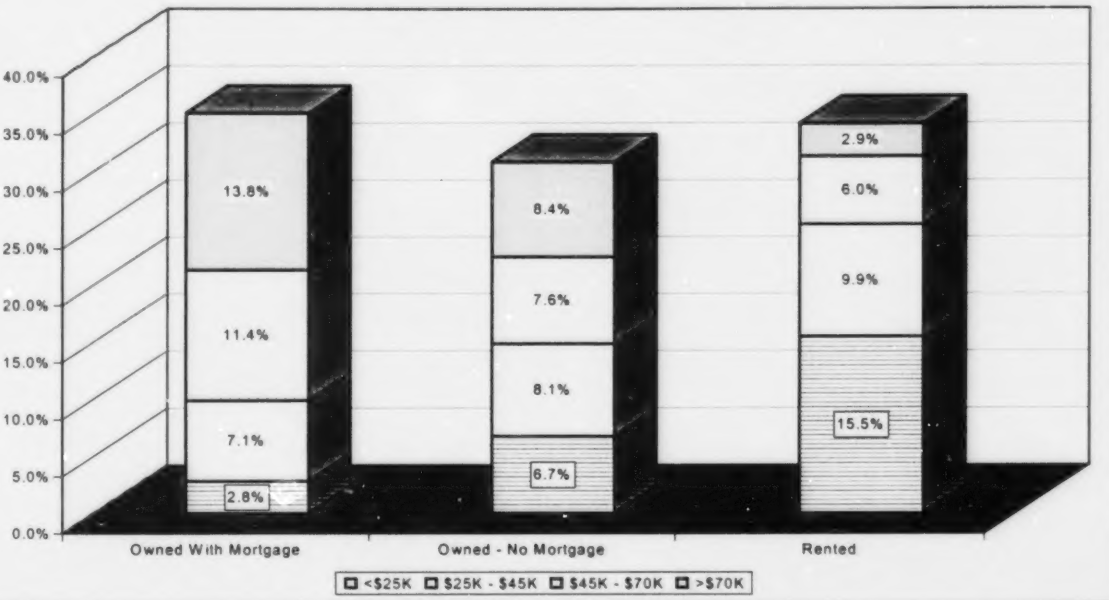
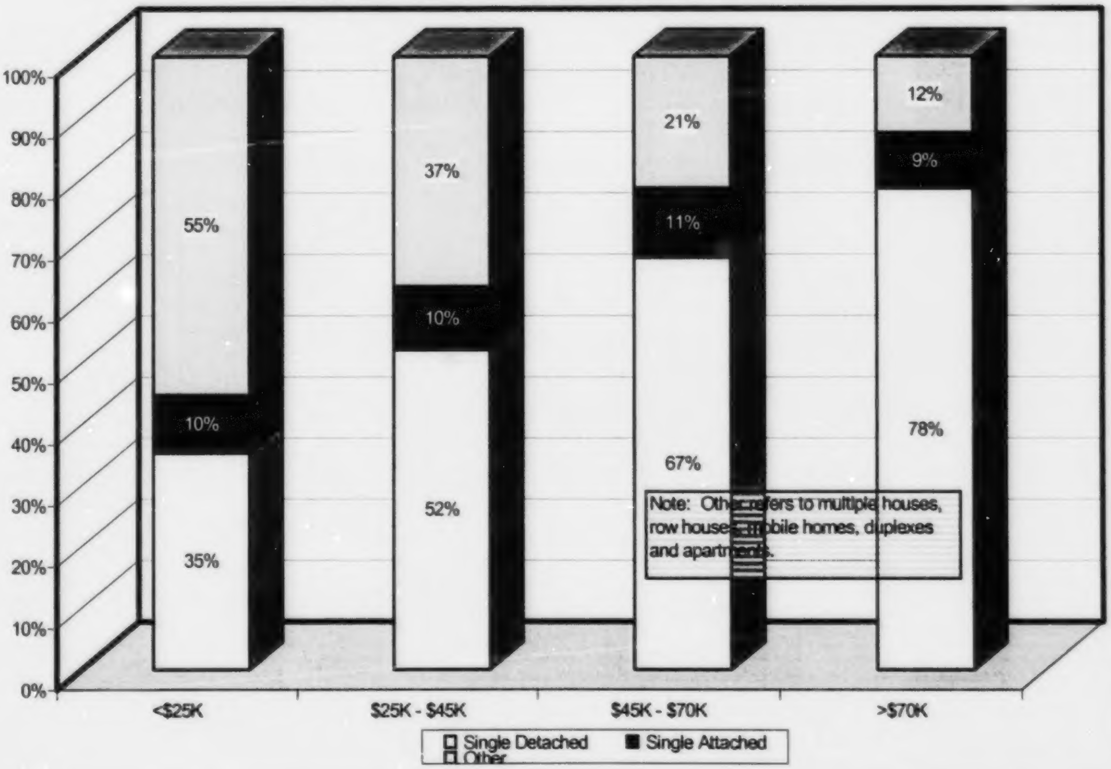


Figure 2.5
Distribution of Income by Dwelling Type, Canada, 1996

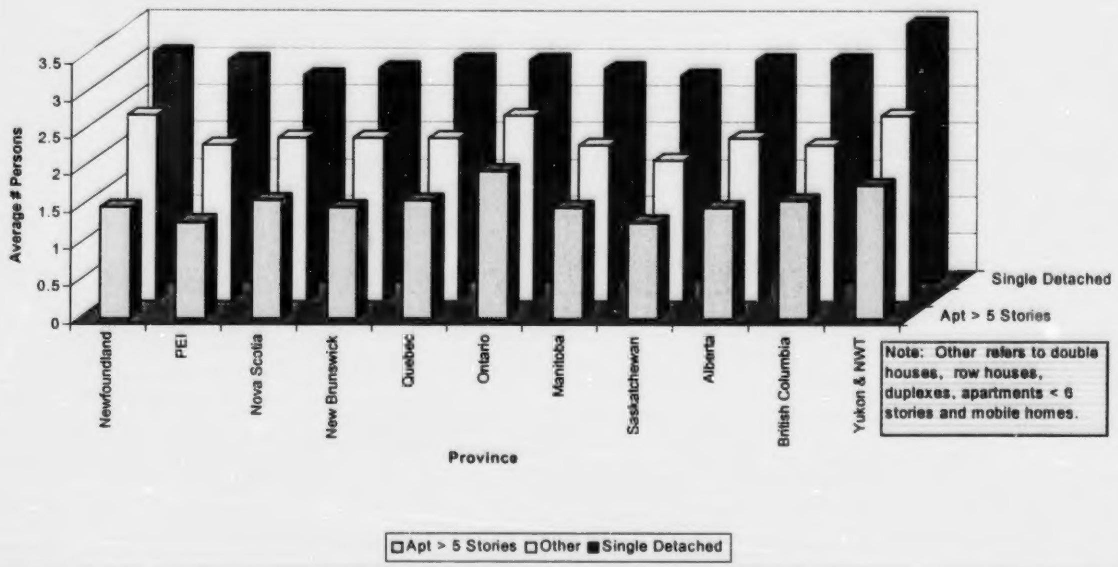


Note: Other refers to multiple houses, row houses, mobile homes, duplexes and apartments.

2.3.3 Household Size

Figure 2.6 profiles, at the provincial level, the average number of persons per household, according to dwelling type. Not surprisingly, the household size increases as one moves from apartments to single detached dwellings.

Figure 2.6
Average Number of Persons per Household, 1996



2.4 THE SIZE OF THE RENOVATION/REPAIR MARKET

The following discussion profiles some of the pertinent characteristics of the renovation, repair and construction market in Canada. Understanding this market is useful when considering policies that attempt to "piggyback" energy efficiency with renovation and construction work in the residential sector.

2.4.1 Distribution By Type of Expenditure

In 1996, the total value of the residential repair and renovation market was between $12 and $14 billion, with the split between labour and materials respectively at 64% and 36%.[4] Figure 2.7 shows how the average dollar is spent among five categories, according to three dwelling types. Particularly in the apartment and other categories renovations and repairs represent the bulk of the expenditures.

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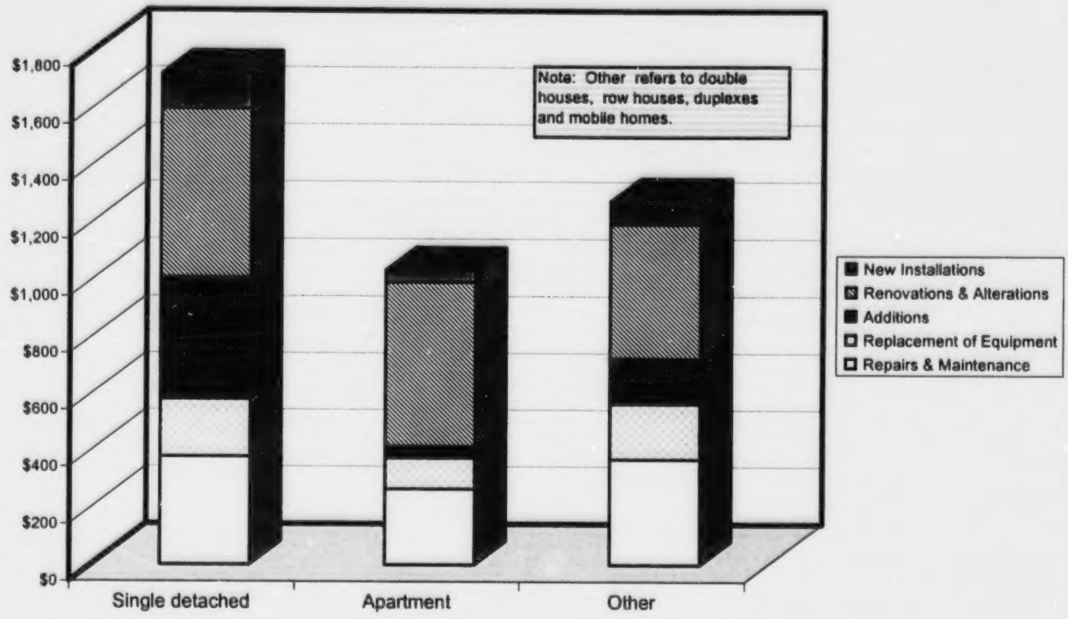
[4] Statistics Canada. 1996. Household Repair and Renovation Expenditures. Catalogue No. 62-201-XPB.

Figure 2.7
Distribution of Average Dollar Expenditure by Expenditure and Dwelling Type, 1996



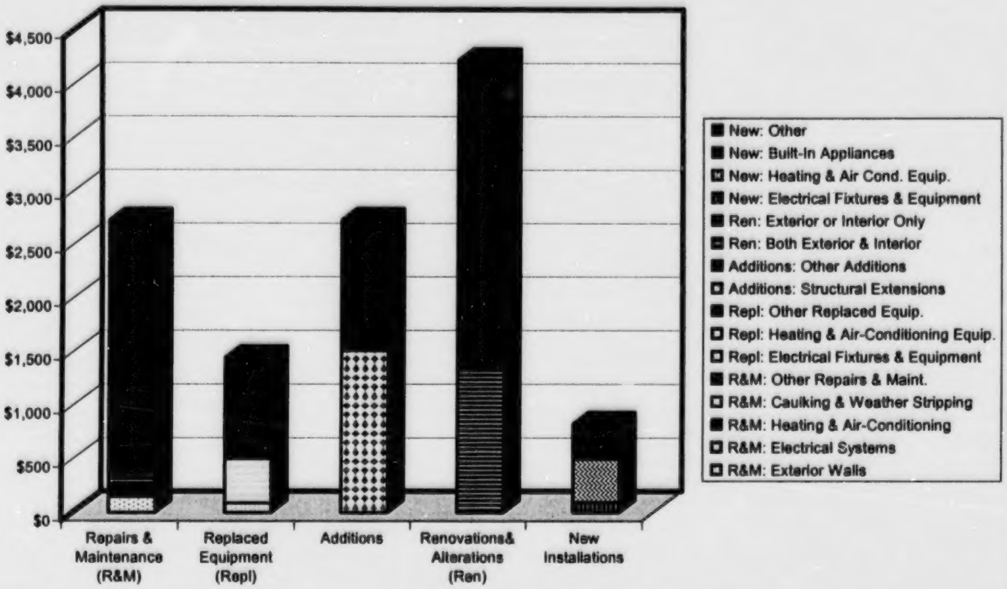
2.4.2 Market Size Relative to the Expenditures Most Amenable to Energy Retrofit and New Construction Piggy-backs

It is generally accepted that energy efficiency measures are most likely to occur when piggy-backed with some form of renovation or construction. These piggy-backing opportunities occur in both existing buildings and during new construction.

Figure 2.8 illustrates what happens when owner-occupied households invest in several categories of renovation and repair. For each of these upgrade categories, we have singled out the type of measures which best represent opportunities for "piggy-backing" energy retrofits and have shown the relative proportion of expenditures represented by these measures in Canada. With the exception of the repairs and maintenance category, potential piggy-backing measures represent a sizeable portion of total expenditures, particularly in the categories of renovations/alterations, additions and replaced equipment.

As to the new home market, it is interesting to note that in the most recent Canadian Home Builder Pulse Survey, roughly a third of the respondents indicated they were planning to add more energy efficiency features as one of the key changes in construction over the next 12 months.[5]

Figure 2.8
Detailed Expenditures of Owned Households, 1996 ($millions)



2.4.3 Age of the Building Stock and Equipment

Dwelling and equipment age is a useful indicator of renovation, repair and replacement potential in which energy efficiency can be integrated. Figures 2.9 and 2.9A profile the overall residential dwelling stock according to the age of dwelling, respectively, for Canada as a whole and at the provincial level. At the national level, more than 20% of the dwellings were built before 1950; while a considerable portion of the stock in this age category will have undergone some renovation, experience suggests that much of this renovation activity did not fully incorporate energy efficiency measures. About 50 % of the dwellings were built after 1970; there is probably a portion of this stock that has never been upgraded. At the provincial level, not surprisingly, central Canada and the eastern provinces contain a considerable percentage of older stock.

Figure 2.9B illustrates the age distribution of space heating equipment in the residential sector. As shown, significant percentages of this equipment stock fall into age brackets where there will be replacement opportunities in the near-term.[6] Obviously the GHG emission impact will be greater for non-electric heating, if the electricity is supplied from non-fossil fuel sources.

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[5] Clayton Research Associates, CHA Pulse Survey Spring/Summer 1998, from detailed survey tabulations.
[6] The category of hot air furnace includes electric forced air units.

Figure 2.9
Distribution by Age of Dwelling

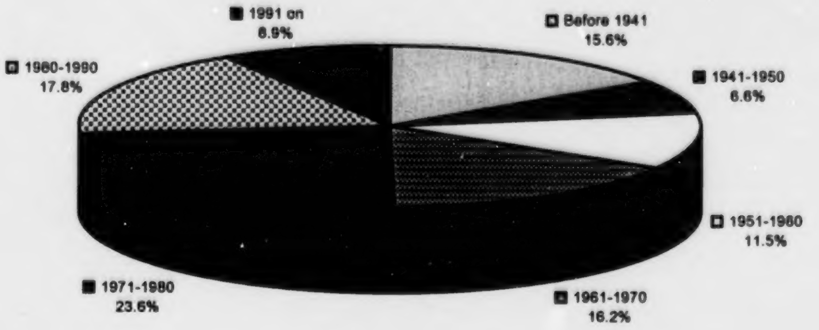
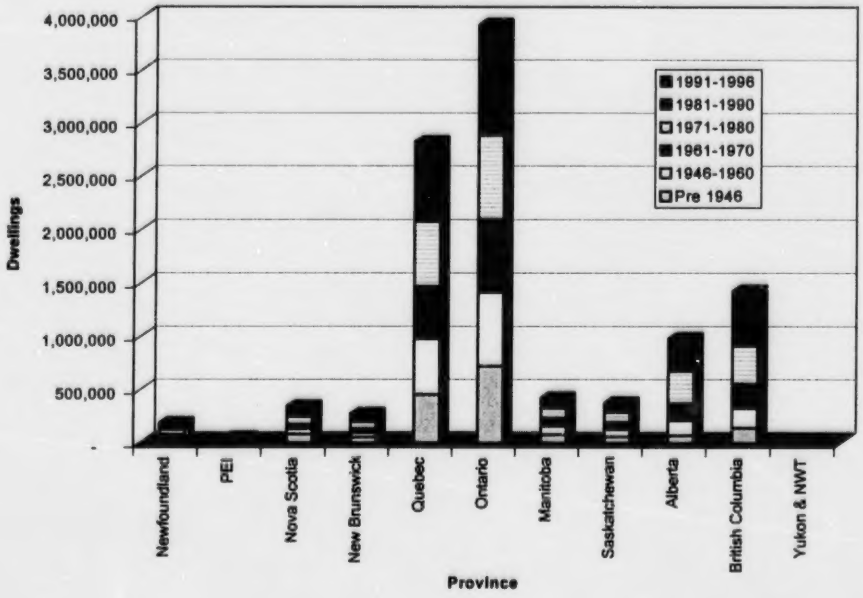


Figure 2.9A
Dwellings by Period of Construction



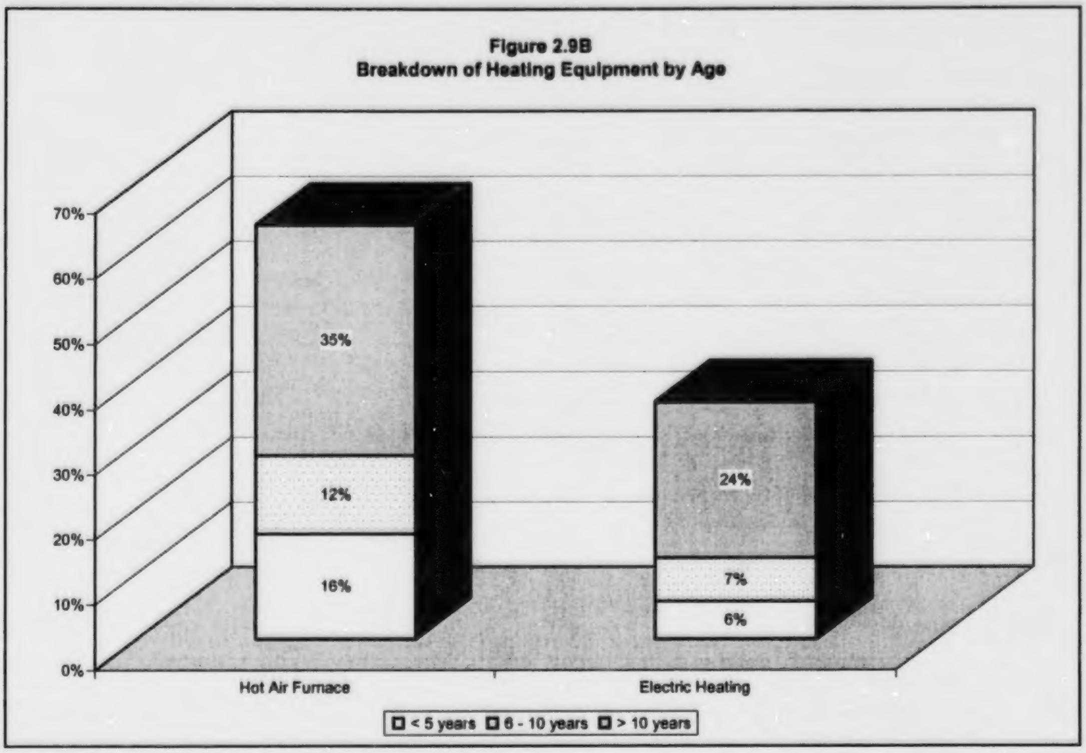


Figure 2.9B
Breakdown of Heating Equipment by Age

2.4.4 Distribution of Income and Repair Requirements

Figure 2.10 illustrates the distribution of repair requirements according to household income levels. Together, major and minor repairs were thought to be required for 20% to 30% of the total stock in 1996, based upon occupant assessments. The requirements are probably higher than shown here, since condition assessments by experts typically reveal many more deficiencies than are apparent to homeowners. There is also some degree of "self-selection bias" involved here as some respondents would not want to admit their home requires substantial upgrades (*this might be particularly true in regard to the low income market segments where one would expect a higher level of repair requirements*).

Figure 2.10
Distribution of Repair Requirements by Income Level

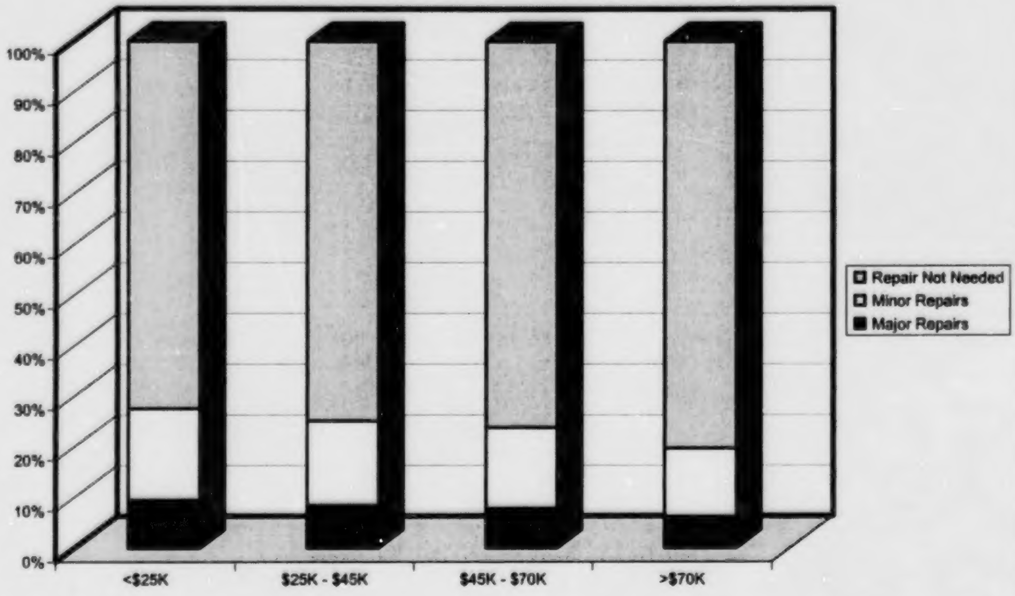
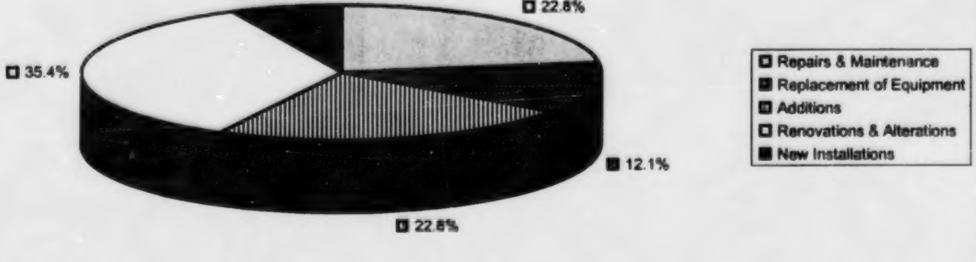


Figure 2.11
Distribution of Average Dollar Expenditures for Housing Repair and Renovation, 1996



2.5 RESIDENTIAL DWELLING STOCK AND OCCUPANCY - LOOKING AHEAD

This sub-section presents a brief examination of anticipated growth of households, with a particular focus on type of dwelling and size of household, both factors which influence energy consumption.

2.5.1 Forecast Households

CMHC projections indicate that roughly 2.5 million new households will be formed between the 1996-2011 period (Note: the dwellings forecast assumes a demolition rate of 1%/annum, for all dwelling types)[7]. This will result in an approximate total of 13.3 million households by 2011. This means that approximately 81% of the forecast households in 2011 exist today.[8] Consequently, it is apparent that the largest market for energy efficiency improvements is in the existing dwelling stock.

CMHC projections indicate no appreciable change in the mix of dwelling type between now and 2016, as a percentage of total dwellings. However, as a percentage of household growth the forecasts suggest a slight shift away from single detached to multi-unit households. For example, forecasts suggest a 4% decrease in the proportion of single detached and about a 3% increase in multiple unit households.

The household projections for the 1996-2011 period indicate that annual household growth will decline in comparison to the growth rates experienced during the 1970s and late 1980s. The primary influencing factor is the declining population growth which, in turn, is influenced by the projected increase in the age of the Canadian population.

2.5.2 Factors Affecting Household Formation: How They Might Affect Energy Use Patterns[9]

Household Size: The Canadian average household size is projected to decline from 2.72 to 2.58 persons per household for the 1996-2011 period. This trend should result in a reduction of energy use for some end-uses, such as hot water and non-major appliances (e.g., electronic equipment).

Household Characteristics: The composition of households will also affect future energy use in the residential sector. In 1996 about 83% of non-family households consisted of one-person households; the other 17% fell into a category of "other non-family". The category of non-family households is projected to grow more rapidly than family households, as a percentage of both total households and household growth (a 75% increase in the growth of one-person households between 1991 and 2016).

Underlying these projected changes in household composition is the ageing population; many one-person households will be comprised of older residents. It is difficult to surmise how the ageing population will affect energy use patterns. Speculating, it is possible that a decline in demand for certain services (e.g., computers and computer related equipment) will be more than offset by a greater demand for more intensive end-uses such as space heating.

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[7] Personal communication, CMHC Research Division

[8] Personal Communication with Canadian Housing Information Centre

[9] Roger Lewis, Research Division-CMHC, The Long Term Housing Outlook, 1997

2.6 ENERGY AND GREENHOUSE GAS PROFILE

2.6.1 GHG Emissions Overview

As has been presented in Chapter 1, there several ways to characterise GHG emissions in the residential sector, depending on which categories of direct and indirect emissions are included in the presentation. In this section we focus on emissions from operating energy consumed on site (called direct energy, secondary energy, or end use energy) as well as emissions from the energy used to generate electricity (electricity emissions). Other indirect residential sector emissions are not included because of a lack of data on their allocation to the residential sector. These indirect emissions include; indirect full fuel cycle emissions from energy consumed on site and from electrical production, emissions from the production of building materials, emissions from construction, renovation, and service work, and emissions from landfill gases, wastewater, compost, and HFC's from air conditioning, refrigeration, and material production.

Table 2.2 provides a breakdown of direct and electrical energy consumption and GHG emissions in the residential sector for 1990 and 1996[10].

Table 2.2 Residential Energy Use and GHG Emissions 1990 and 1996

Energy Source	**1990 Energy Consumption** (PJ/Year)	**1996 Energy Consumption** (PJ/Year)	**1990 GHG Emissions (Mt/year)**	**1996 GHG Emissions (Mt/year)**
Direct Energy				
Natural Gas	528	696		
RPP's (Heating oil, etc.)	193	158		
Propane, wood, coal	113	107		
Total Direct Energy	834	961	44.1	~46.7
Electricity	468	492	24.3	~26.0
Total	1294	1453	~68.4	~72.7

Between 1990 and 1996 residential sector direct greenhouse gas emissions increased by approximately 5.9% and electricity emissions by 7%, for a total increase of direct and electricity emissions of approximately 6.3%. As a percentage of Canada's total GHG emissions the residential sector represents the following:

◊ % of Total Canadian GHG Emissions: Residential sector emissions from direct and electrical energy represented 12.9% of all of Canada's greenhouse gas emissions in 1990, and 12% in 1995[11].

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[10] These numbers are from a compilation of data from Natural Resources Canada, Energy Efficiency Trends in Canada, 1990 to 1996, June 1998, Natural Resources Canada Canada's Energy Outlook 1996-2020, 1997, J. Gusdorf, NRCan Buildings Group, Background Information on Greenhouse Gas Emissions from Canadian Housing, October, 1998.

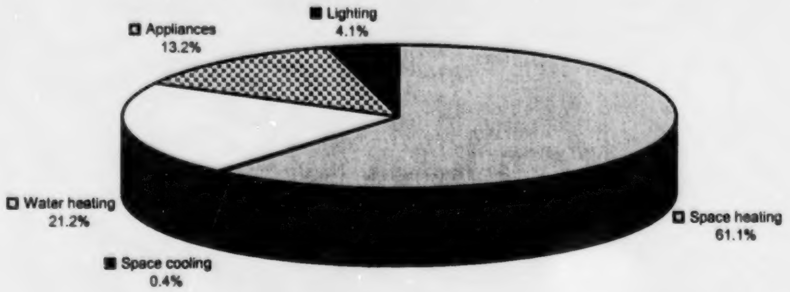
[11] J. Gusdorf, NRCan Buildings Group, ,Background Information on Greenhouse Gas Emissions from Canadian Housing, October, 1998.

◊ % of Secondary Emissions: If GHG emissions from electrical generation are included in Canada's total secondary (or end use) greenhouse gas emissions, then the residential sector emissions from direct and electrical energy represented 18.4% of all secondary energy related greenhouse gas emissions in 1990, 17.5% in 1995[12], and 17.1% in 1996. If residential electrical emissions are excluded, then residential sector direct GHG emissions represented 14.2% of secondary emissions in 1990 and 14% in 1995. The latter numbers are the figures most often cited in official forecasts.

2.6.2 Energy Overview

In 1996, the residential sector accounted for about 19% of total secondary or end use energy use in Canada. Energy use increased by 12.3 % in comparison with the situation in 1990. Figure 2.12 shows that space and water heating together account for about 82% of total energy consumption; space heating accounts for 61%. There has been virtually no change in this distribution by end-use since 1990.

Figure 2.12
Distribution of Residential Energy Use by End-Use, 1996



The pattern of energy use, by end-use, varies somewhat among dwelling types. For example, the share attributed to space heating, in single detached dwellings is approximately 60%. When one moves to mid- and high-rise apartment buildings, the share for space heating changes somewhat. Estimates for high-rise, for example, range from 28% to 60%.[13] As one moves from low rise to increasingly larger residential structures, the range of energy services expands (e.g., corridor ventilation, elevators, central air conditioning, swimming pools, etc.).

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[12] Ibid

Not surprisingly, energy use levels vary according to type of residential structure. A comparison of dwelling type energy use on a per floor area basis, for the total existing dwelling stock, reveals the following:

Single detached:	178 kWh/m2/yr.
Attached Row	156 kWhr/m2/yr
Mid and High Rise Apartments	274 kWh/m2/yr.
Mobile Homes	437 kWhr/m2/yr

(See Table 3.5 for sources for these figures)

While it should be expected that multiunit residential buildings consume much less energy than single detached houses on a per floor area basis because of reduced exterior surface area, they are not generally built to high levels of energy efficiency. Row housing is generally more efficient on a per floor area basis. However, mid and high-rise multiunit residential buildings consume significantly more energy than single detached houses when the energy consumption of the entire building stock of multiunit residential buildings is compared to that of single detached houses as shown above. In new construction, annual energy consumption is comparable between high-rise and single detached buildings.[14] On the other hand, multiunit residential buildings consume less energy than single detached housing on a per occupant basis, due to the smaller floor area per occupant found in this type of housing.

Figure 2.13 illustrates the distribution of residential energy use by fuel type. As shown, natural gas continues to be the predominant fuel and its share has grown since 1990, relative to electricity and oil. According to NRCan, this shift from other fuels to natural gas has helped contribute to a reduction in the CO2 intensity of energy use in the residential sector.[15] Figure 2.14 illustrates the CO2 emissions, by end-use, in the residential sector. Not surprisingly, this distribution corresponds largely with the break-down of actual consumption by end-use.

From 1990 to 1996, residential energy use increased at twice the rate of carbon dioxide emissions (12.3 % vs. 6.2%). The decline in the carbon dioxide intensity of energy use is due largely to the changes in the fuel mix at both the electricity generation and end-use levels. There was a gradual trend away from oil to natural gas.

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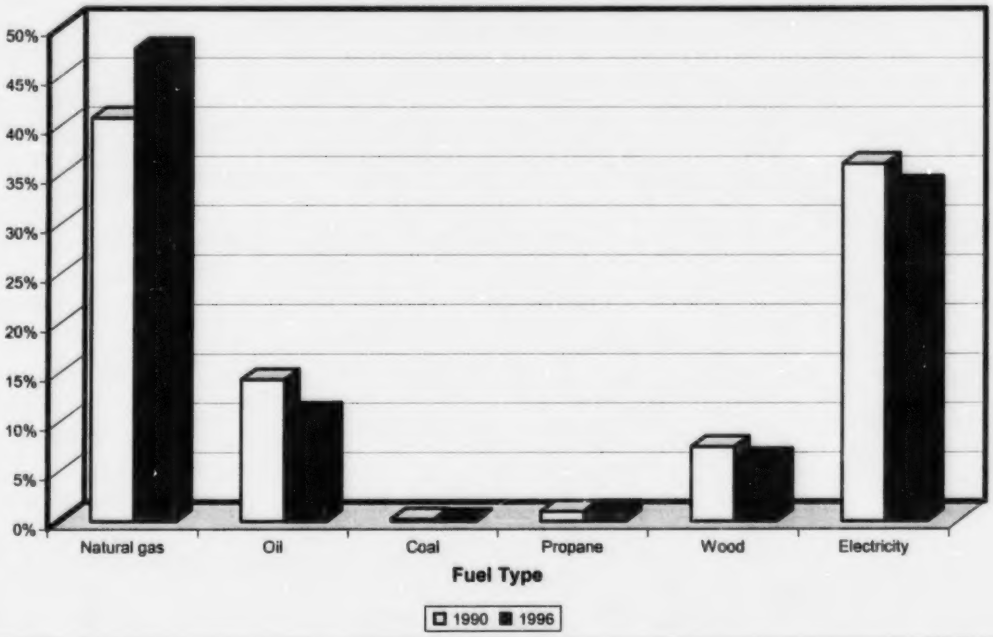
[13] Op cit. And CMHC R&D Highlight Technical Series 97-100.

[14] CMHC, Research and Development Highlights, Energy Audits of High-Rise Residential Buildings, 97-100.

[15] Op cit, p.13.

It will be difficult to project the future influence of electric power generation on carbon dioxide intensity in Canada. There is significant variation of generation fuel mixes at the provincial level and this is going to change due to such factors as power sector restructuring.

Figure 2.13
Residential Energy Fuel Shares, 1990 and 1996



2.6.3 Factors Influencing Energy Use in Dwellings: The 1990-1996 Period

Natural Resources Canada has provided a rich data set of residential energy which helps illustrate how and why certain energy use patterns have emerged in the residential sector and how various factors influence this usage. It is an understanding of these influencing factors that is particularly important in establishing a foundation for discussions of measures and GHG reduction impacts

In particular, the data show that:

- Overall energy use in the sector, and resulting GHG emissions, is growing.
- The energy use per dwelling is also growing, after a decline in the 1990-1995 period.

If we investigate the factors that contribute to energy use in the residential sector, it is evident that household growth and other structural factors have more than offset decreases in energy use due to improvements in energy efficiency, in terms of equipment and dwelling design and thermal performance. This situation is further elaborated with a brief discussion of these offsetting factors.

Factors Helping to Reduce Energy Use and GHG Emissions

Energy Intensity is a measure of the performance with which specific energy services are provided to Canadian households. In 1996, the average energy intensity of all residential services was about 6.3% lower than in 1990, if adjusted for weather and structure effects.[16] The reduction of space heating intensity accounts for almost all of this improvement which, in turn, has been influenced by several key factors:

- The proportion of newer to older homes increased, resulting in a larger penetration of more thermally efficient dwellings.
- There has been a significant market penetration of more efficient gas and oil furnaces (which has been positively influenced by minimum energy performance regulations).

Another key contributing factor to the reduction of overall energy intensity has been that annual energy use of major appliances has decreased significantly (e.g., the overall stock weighted efficiency of refrigerators improved about 23% between 1990 and 1996.)[17]

Factors Offsetting Improved End-Use Efficiencies

Household Growth: The major factor offsetting improved end-use efficiencies is household growth. According to NRCan, household growth is the key driver of residential energy demand.[18] Between 1990 and 1996, about 1 million new households were created in Canada, a 12% increase which matches the increase in aggregate energy use during the same period.

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[16] Natural Resources Canada, Energy Efficiency Trends in Canada 1990-1996, 1998.

[17] Ibid., p.23.

Structure: This is referred to, by NRCan, as the saturation and mix of energy-end uses in dwellings (e.g., number and type of appliances, degree to which households are centrally air conditioned). The most significant structural factor during the 1990-1996 period has been the growth in the share of appliance energy use. While the saturation of major appliances, such as fridges and washing machines, has remained relatively stable during this period, there has been a large increase in penetration of computer equipment (100% increase) and peripherals, as well as home entertainment (e.g. 250% increase of compact disk players).

Other Important Structural Factors: Other housing design and construction trends have helped to offset decreases in energy intensity in homes. Among the more significant factors are:

- ***Increasing house size*** - The NRCan/CANMET Buildings Group recently investigated the trend of increasing house size which revealed that, since roughly 1950, the average size of single detached houses has been growing (e.g., 1.4%/year during the 1983-93 period.[19] The most recent Canadian Home Builder "PULSE" SURVEY indicates that 35% more respondents were going to build smaller dwellings in the next 12 months, compared to the past 12 month period.[20]. However, the remaining 65% are still planning to build the same size or larger houses, resulting in a net increase.
- ***Decreased household size*** - The trend of decreasing number of occupants per household has resulted in a greater heated floor area and thus energy consumption on a per person basis.
- ***Elevated Housing*** – In some regions basements are being elevated, or replaced with crawl spaces, leaving more of the house envelope exposed to outdoor temperatures.
- ***Increasing window area***. Improved window technologies, and consumer preference, have contributed to increases in the percentage of envelope dedicated to windows. Since windows are typically the least efficient portion of the building envelope, energy requirements increase.
- ***Larger water heaters*** - In many regions the standard water tank has increased from 40 to 60 gallons, to better meet expanding demands for hot water services (e.g., larger Jacuzzi tubs). Hot water consumption increases, as do standby heat losses.

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[18] Ibid.

[19] John Gusdorf, NRCan, Background Information on Greenhouse Gas Emissions from Canadian Housing, October 1998.

[20] Clayton Research Associates, CHA Pulse Survey Spring/Summer 1998, from detailed survey tabulations.

- ***Increased lighting*** – An increase in landscape lighting, and indirect indoor lighting, have increased overall lighting loads in new housing.
- ***Hybrid heating systems*** – Many new developments now install hybrid heating systems in homes to improve comfort and aesthetics. This may include combining electric resistant baseboards with one or more gas-fired fireplaces, and infloor radiant heating on the main floor.

2.7 FACTORS INFLUENCING ENERGY USE IN DWELLINGS: LOOKING AHEAD

We have seen how significant gains in energy efficiency have partially offset other factors that contribute to growing use of energy and CO2 emissions in the residential sector. Despite these gains in energy efficiency there has been a substantial net increase in energy use. With the 2008-2012 period only ten years away, a key question is whether significant technical improvements will be large and occur fast enough to result in a major reduction of energy and CO2 emissions. We know that NRCan will soon be preparing an update to the department's outlook on energy use to 2020, which will re-examine projections of energy use and contributing factors. This outlook may confirm some of the challenges, particularly that:

- Some of the countervailing trends such as increasing house size and window area will continue.
- There will be decreasing efficiency gains, as many of the easy, low cost improvements have already been captured.

Pending release of this information, we present the following observations.

- ***Appliances***: Looking ahead to 2010, it appears that continued increases in the energy efficiency of major appliances will be partially offset by continued increases in the penetration of electronic equipment and minor appliances. For example, according to some recent analysis undertaken by the NRCan/CANMET Buildings Group, minor appliance energy use is projected to increase by 15% during this period. Coupled with a forecast increase in the number of households of 15%, only a 3% to 4% decrease in the amount of energy used by appliances is projected.

- ***Housing:*** The 1996 NRCan Energy Outlook assumed that 98% of new homes built in 1998 would perform to levels expected under the Model National Energy Code for Houses (MNECH). In fact, not a single province or jurisdiction has yet adopted the MNECH, and hence this estimate is grossly optimistic.[21]

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[21] Michael Margolick, An Assessment of the Greenhouse Gas Emissions Projections in Natural Resources Canada's Energy Outlook, 1996-2000., Feb. 1998.

2.8 INFORMATION GAPS AND AREAS FOR FURTHER RESEARCH

1. Additional analysis of who the primary energy management decision-makers are under different circumstances (building construction versus operation) and market sub-sectors.
2. Additional analysis of the degree to which different players act as key influencers on energy management decision-makers.
3. Investigation of the financial value to the economy of energy management investments, both direct and indirect (including employment impacts).
4. Analysis of energy use patterns and intensities of non-major appliances such as outdoor equipment (barbecues, hot tubs, lawnmowers, etc.) and TVs, and home entertainment equipment, etc.
5. Analysis of how decisions made at the level of the households affect transportation energy use patterns.
6. Development of a database on energy use, physical characteristics, and renovation cycles of multi-unit dwellings using methods recommended in a recent report for CMHC.[22]
7. Examine how to piggyback energy savings as part of the renovation and repair of MURB stock.
8. Further analysis on the quantity of non direct GHG emissions that are attributed to the residential sector (from materials, upsteam fuel emissions, landfill gas etc.)
9. Further analysis of residential electrical emissions (we found fairly wide discrepancy and disagreement among different sources for both 1990 figures and other years).
10. Further investigation of the degree to which non-energy factors such as house size is trending in the residential market and the impact on energy use and GHG emissions.
11. Further investigation to estimate and assess the distinction between GHG emissions resulting from the design of dwellings versus the behaviour and actions of dwelling occupants.

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[22] Sheltair Scientific, in association with Marbek Resource Consultants and Medhurst Hogg Sobottka Leong Assoc. Ltd., Feasibility of a Database of Canadian Multi-Unit Buildings, prepared for CMHC, 1998, p.69.

3.0 WHAT CURRENT TECHNOLOGIES AND LIFESTYLE CHANGES REPRESENT OPPORTUNITIES FOR REDUCING RESIDENTIAL GHG EMISSIONS?

This section presents a review of potential technological and behavioural change approaches for reducing GHG emissions in the residential sector. Opportunities for GHG reduction in various lifecycle stages of the building are presented with the emphasis placed on those opportunities with the greatest potential to reduce emissions. Greenhouse gas reduction opportunities are presented within the following broad categories:

- Dwelling Growth Rate
- Initial and Recurring Embodied Energy
- Changes in Occupant Behaviour
- Operating Energy
    - End Use Energy Efficiency of Residential Services and Whole Buildings
    - Fuel Switching
    - Alternative Energy supply Systems
    - Shared Energy Supply Systems

For each potential opportunity we present a description and where possible, an assessment of the impact on GHG reduction, and associated costs and benefits. Policy and programs that support these opportunities by targeting specific groups of decision makers are not discussed here but are presented in the following chapters.

Where available from previous research, the technical potential for GHG reduction from new housing and housing stock retrofits are presented, for different dwelling types. While the energy reduction potential in single family dwelling stock has been well studied and documented, very little previous research has been carried out in Canada on the potential for energy savings in the multi-family building stock (especially opportunities for buildings four stories and over). As a result, the majority of information in this section is focussed on the single family dwelling stock. Where information specific to multifamily residential buildings is available it is included.

In addition, an assessment of the technical potential has been performed for various options using the Residential Energy & Economic Simulator (REES), a spreadsheet-based program created by SAR engineering Ltd. for CMHC/NRCan to determine the costs and benefits of a variety of residential retrofit programs. The thermal calculation "core" of the REES program is based on the algorithms of the HOT-2000 thermal simulation program, including calculation of foundation losses (Mitalas model) and infiltration (AIM-2 model). The program contains 965 actual single-detached houses using an expanded CMHC STAR database, representing a cross-section of housing types and ages across Canada. GHG emissions from each house are modelled using current local energy supply emissions. New and retrofit option simulation results are extrapolated to the housing stock across Canada (by region and age group), and then, using projections of new housing starts and demolitions, to the year 2030.

3.1 REDUCED DWELLING GROWTH RATE

As has been pointed out previously, the greatest influence on increased energy consumption and resulting GHG emissions in the residential sector in the period between 1990 to 1996 was the growth in the number of households in Canada. The increase in energy consumption due to the level of activity more than offset energy reductions due to improved energy efficiency. Therefore it is definitely worth considering opportunities for reducing GHG emissions through reducing the growth in residential sector activity level.

Reducing the activity level can be accomplished through:

1. Reducing the need for new dwelling spaces - The need for new dwelling spaces can be reduced by encouraging the development in existing buildings of secondary suites and granny flats, or through programs such as distance education and in-home care services.

2. Reducing the size of new dwellings - The size of single detached housing has increased steadily from the 1950s, initially increasing at about 1% per year, and then rising recently to 2% per year.[23] A reversal in this trend through a change in expectations of new home purchasers could bring about significant reductions in activity growth. By favouring quality of design over quantity of space, homeowners can spend more on details that define the character of a home than on simply making it bigger. Smaller houses can be much more comfortable and consume less energy.

3. Improved use of presently under-utilised spaces - Basements constitute a significant fraction of the total occupied space in Canadian housing, but are presently under-utilised. Designs to improve the aesthetics and liveability of basements could result in smaller 'main-floor' areas, with reduced overall energy use[24]

4. Encouraging Compact Urban Form - Increased use of multi unit residential buildings has the potential of reducing both the level of activity and the energy intensity in the residential

TABLE 3.1 Energy Consumption on a per Occupant Basis

	1993 Avg. No. occupants	Energy Use Per dwelling (GJ/y)	Energy Use Per Person* (GJ/occ./y)
Single Detached	2.97	151	51
Attached, Row	2.92	109	37
Apartment	1.92	82	43
Mobile	2.62	114	44

*Assuming occupancy remains constant from 1993 to 1996 sector. The energy consumption of multifamily buildings is higher than that of single-family detached residences if measured on an energy per unit of floor area basis for the existing housing stock, and comparable for new buildings.[25] However, as shown in Table 3.1[26], the average per person floor area of single family homes is much greater than the average per person floor area of multi- unit buildings. As a result, the average energy consumption on a per person basis is also lower. The average energy use in the existing housing stock on a per occupant basis is about 37 GJ per year for attached dwellings, compared with 43 GJ per year for apartments, and 51 GJ per year for occupants of single detached dwellings. As a result, there is a definite advantage to promoting higher density housing as a method of reducing energy consumption and GHG emissions. These advantages are in addition to advantages of reduced requirements for services and transportation which are traditionally thought of as the main benefits of promoting increased densification.

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[23] J. Gusdorf, Background Information on G[illegible] Buildings Group, October, 1998

[24] Cold Climate Design House (R-2000 house in Edmonton, AB) is an example of an energy efficient attached house with a livable basement. Total floor area of 171 m^2 is less than Canadian average of 186.5 m^2. Monitored energy use averaged 21.9 GJ per person per year. [12].

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[25] CMHC, Research and Development Highlights, Energy Audits of High-Rise Residential Buildings, 97-100.

[26] See reference for Table 3.5 for explanation of references for these figures.

3.2 REDUCED INITIAL AND RECURRING EMBODIED ENERGY

Initial embodied energy refers to the energy required to extract the raw or recycled materials used in constructing buildings, the processing of these materials, their transportation, secondary fabrication, and installation on-site. "Life-cycle" embodied energy expands the analysis to include embodied energy used throughout the life-cycle of a building, including the energy for maintenance, repair and replacement of building components (recurring embodied energy), and the energy required to demolish and haul away the structure at the end of its lifetime (but does not include operating energy).

While energy consumption and GHG emissions from the manufacture of materials is dealt with by the Industrial Table, actions taken in the residential sector have significant impacts as well. Initial and lifecycle embodied energy profiles for a new Canadian wood frame three bedroom house in the lower mainland of British Columbia [27] are shown in Table 3.2.

Similar profiles for a new multiunit residential building are shown in Table 3.3. This building is an 84 unit, 4 story, concrete structure multiunit residential building with steel stud/brick exterior walls, located in Ottawa Ontario.[28]

Table 3.2: Initial and Lifecycle Embodied Energy in a Canadian 3 Bedroom House

Material	Initial Embodied Energy [%]	Lifecycle Embodied Energy [%]
Lumber & Timber	12%	10%
Ready Mix Concrete	11%	10%
Aluminium Alloys	11%	7%
Plastic Piping and Fittings	9%	12%
Plywood and Veneers	7%	6%
Copper Fabricated Materials	4%	2%
Gypsum Products	4%	4%
Vinyl Floor	4%	2%
Carpet	4%	14%
Mirrors and Glass	3%	2%

Table 3.3 Initial and Lifecycle Embodied Energy in a Canadian Concrete Structure Four Story Multiunit Residential Building

Material	Initial Embodied Energy [%]	Lifecycle Embodied Energy [%]
Concrete Work	45%	28%
Finishes	13%	23%
Mechanical	13%	13%
Door & Windows	5.8%	8%
Metals	4.4%	5%
Site Work	4.3%	5%
Thermal & Moisture Protection	4.2%	4%
Masonry	3.9%	5%
Electrical	3.4%	4%
Specialities	1.3%	2%
Wood & Plastic	1.0%	2%
General	0.3%	0%

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[27] Canadian Mortgage and Housing Corporation, OPTIMIZE, A Method for Estimating the Lifecycle Energy and Environmental Impacts of a House, Ottawa, 1995.

[28] Sheltair Scientific Ltd, Cole Associate Architects Inc, Analysis of the Embodied Energy of the Conservation Co-op, June 1998

The initial embodied energy for the single family house accounts for approximately 10% of the total life-cycle energy (including operating energy). Initial and recurring embodied energy together (total life cycle embodied energy) account for 20% of the total life-cycle energy of the house. Depending on the life-span, the life-cycle embodied energy for office buildings may be 18% to 40%[29] of the entire life-cycle energy budget of a building. Multiunit residential buildings are also in this range depending on the type of construction.

By reducing the operating energy of a building through improved energy efficiency, the embodied energy will become a more significant component of the total energy budget. However, the embodied energy of materials has also been decreasing over time. Between 1971 and 1986, there was a 20% decrease in energy intensity for steel, a 24% decrease for non-ferrous metals, and a 33% decrease for cement[30]. These rates of change in energy intensity may not be sustained into the future, but it is assumed there will continue to be significant reductions in energy intensities. For example, the work by CANMET predicts the energy intensity of steel produced in Canada will decrease from 27 GJ/Tonne in 1989 to 11.9 GJ/Tonne in 2010.[31] The Canadian Portland Cement Association projects that by the year 2000, total emissions associated with domestic cement consumption will be 6% below 1990 levels[32]

Reducing the embodied energy of a building can be achieved through a number of means, such as:

- Increasing the useful life of buildings and their assemblies.
- Reducing the energy intensity of building materials, such as fly-ash substitution in concrete. Concrete is one of the greatest areas of potential for embodied energy related GHG reduction because it is one of the largest embodied energy sources in most buildings. In the single family building and the low rise concrete structure apartment profiled above, concrete accounts for about 2% and 6% to 11% respectively of total lifecycle energy. The embodied energy in concrete can be reduced through the use of fly ash, silica fume, and blast furnace slag substitution. Another opportunity for houses is the use of concrete insulating forms (ICF).
- Reducing the amount of material within a building, such as with the elimination of false ceilings, or additional flooring material over concrete floors.
- Use of advanced framing techniques such as elimination of unnecessary 2x6's, and using trusses, I-joists, etc.
- Reducing construction waste.
- Increasing the amount of recycled material in a building, such as using recycled bricks, timbers, or recycled content materials

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[29] Cole, R.J., Ed., Buildings and the Environment, Proceedings of a one day Forum held at the University of B.C., School of Architecture, University of British Columbia, Vancouver, 1991

[30] Statistics Canada, 1993

[31] CANMET, pg. xiii, 1993

[32] Canadian Portland Cement Association, Concrete Contributions to Meeting Canada's Kyoto Commitment, September 1998.

- Using materials and assemblies that require less maintenance and renewal, eg. durable hard flooring instead of carpet
- Using less energy intensive building materials during maintenance and repair
- Using local instead of imported products to reduce the associated embodied transportation energy.

3.3 CHANGES IN OCCUPANT BEHAVIOR

Occupant behaviour can have a large impact on GHG emission reduction. Ultimately a person's energy consumption and conservation levels are culturally dominated and vary systematically on the basis of social class, ethnicity, life-cycle stage, gender, occupation, education, geographic location and local culture. How occupants operate and maintain the building and its equipment, the level of service expected by building occupants, and the purchasing decisions that they make are all very important factors influencing energy consumption and GHG emissions.

Occupants can change their behaviour in operating and maintaining their buildings to use energy more efficiently without reducing the level of service provided to them. As an example, a study that looked at the potential for reducing electrical consumption in BC found that if we operated and maintained our current residential equipment in the most efficient manner we could reduce refrigerator electrical consumption by 25%, clothes washers by 84%, and clothes dryers by 21%. Electrical reduction potential identified in the report for various services are shown in Table 3.4.

Occupants can also make choices as to the level of energy services that they require. They can turn down the set point for heating thermostats, turn up the set point for air conditioning thermostats, or not use air conditioning at all, choosing to live with comfort conditions that vary slightly with the outdoor climate. Or they can eliminate the use of services that consume energy by using manual appliances instead of power appliances, such as manual can openers, lawnmowers, hedge trimmers, shovels instead of snow blowers, etc. The elimination of services altogether is another choice occupants can make. Landscape lighting, extra exterior lighting, appliances with standby losses, etc. can be eliminated altogether.

The choice of level of service is generally a lifestyle choice that is part of our culture, and can be difficult to influence. However, policies can be used to create a change in social policy to make energy wasting behaviour socially unacceptable, and promote the concept of energy conservation rather increased energy efficiency.

Purchasing decisions made by building occupants also affect energy consumption and greenhouse gas emissions. Whether or not to buy an energy efficient new home, include energy efficient upgrades in retrofits, or purchase energy efficient equipment or appliances are decisions influenced by purchasing behaviour. While many energy efficiency improvements are already cost effective and make sense in their own right, they do not occur because of market barriers to their adoption or individual decision making.

Examples of barriers include irrational decision making, lack of information, high discount rates, momentum of past behaviour, split incentives, etc. These barriers and their implications on occupant behaviour are discussed in greater detail in Chapter 5.

Building Operation or Maintenance Practice	Potential for Electrical Savings (%)
Building Envelope	(% of Space Heat Load)
Window cleaning and opening Drapes to improve solar heating	2%
Upkeep of weather stripping	3%
Closing Fireplace Dampers	2%
Space Heating And Cooling	
Setting back temperature for part of day without sacrificing comfort	10% of heating load
Regular cleaning of furnace filters	3% of heating load
Use of curtains, shutters, and trees to reduce air conditioning	25% of cooling load
Domestic Hot Water	
Use of low flow water taps and showerheads, and turning off hand washing taps as soon as possible	30% of water heating load
Refrigerators	
Cleaning refrigerator coils, defrosting regularly, selecting a size no larger than needed, locating in a cool area of dwelling	26% of refrigerator energy
Freezers	(% of freezer energy)
Locating away from heat sources and defrosting annually	4%
Optimised temperature setting and cleaning condenser coils	2%
Choosing correct size that is not larger than needed	20%
Clothes Washers	(% of clothes washer and water heating energy)
Using only cold water washes	88%
Using full loads instead of partial loads	10%
Clothes Dryers	(% of Clothes Dryer Energy)
Using clothes lines when feasible	25%
Drying only full loads	40%
Dishwashers	
Turning off electric dish dryers	9% of dishwasher energy
Electric Ranges and Microwaves	(% of average range & microwave energy)
Greater use of microwaves instead of oven cooking	15%
Greater use of pressure cookers and crockpots	30%
Lighting	
Turning off unnecessary lights	18% of lighting energy
Minor Appliances	
Turning off televisions when not in use	15% of television energy
Turning on car block heaters one hour before use instead of leaving them on all night	90% of block heater energy
Insulating and covering waterbeds	30% of water bed energy

Table 3.4 Potential Electrical Savings from Changes in Operation and Maintenance Behaviour[33]

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[33] Collaborative Committee for the 1991-1994 Conservation Potential Review, Electricity Conservation Potential Review, 1998 -2010, The Residential Sector, Phase 1: Unconstrained Potential, 1993.

3.4 REDUCED OPERATING ENERGY

Operating energy consumed during the occupancy stage of the life of the building is comprised of energy to provide a variety of services. These services include comfort control (heating, cooling), air quality (ventilation), hot water, lighting, clothes washing and drying, food storage (refrigerator, freezer), food preparation (cooking), communications and entertainment (TV, radio, computers, etc), hobbies and personal hygiene. In addition, energy is used outside the dwelling for lighting, garden equipment (mowers, etc.), vehicle block heaters, swimming pools, hot tubs, barbecues.

In this section we explore the opportunities for reducing GHG emissions that are attributed to direct energy consumption on the site, as well as those associated with electrical generation but not include upstream energy emissions from energy consumption.

Key characteristics of the current residential dwelling stock that are relevant to a discussion about operating energy GHG reduction opportunities are shown in Table 3.5. The number of dwellings, average size, and operating energy use characteristics are presented for different dwelling types. The figures for energy consumption on a per unit and per floor area basis shown in Table 3.5, as well as the figures for energy consumption on a per person basis shown in energy figure 3.1, were derived from correlating the total number of 1996 dwellings and their characteristics, to total 1996 residential energy consumption.

The total housing stock in 1990 was 10,233,000 dwellings, increasing to 11,446,000 in 1996. While single detached, attached and row houses represented 66% of the total number of dwellings in Canada in 1996 they consumed about 77% of the total energy use. These types of housing have similar envelopes and heating systems, and thus similar opportunities for energy improvement strategies.

Table 3.5 1996 Residential Dwelling Stock Characteristics[1]

Building Type	Number of Dwellings[34] (1996)	Main Floor Area[35] (sq. m.)	Total Building Floor Area (sq. m.)*	Avg. Energy Per Dwelling[36] (GJ/Yr)	Avg. Energy Per Unit Area (kWh/m2/yr)	Total 1996 Energy Use (PJ)	% of Total Energy Use
Single Detached	6,329,638	133	237	151	178	958	68%
Attached, Row	1,201,830	108	194	109	156	131	9%
Apartment	3,697,058	83	83	82	274	304	21%
Mobile	217,474	73	73	114	437	25	2%
Total Dwellings	11,446,000					1417	

* including basements, assuming areas increased 4% from 1993 to 1996

Interactions Between Components

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[34] NRCan, Energy Efficiency Trends in Canada, 1990 to 1996, June 1998,

[35] Natural Resources Canada, 1993 Survey of Household Energy Use, National Results (also ***Provincial Results*** and *Technical Appendix*), November 1994

[36] NRCan numbers from personal communication with Crostobal Miller, NRCan.

It is important to understand how interactions between systems within the building and energy supply sources can reduce the potential emission reductions from individual components.

Energy consumed by lighting and appliances inside the building reduces the building's space heating load during the heating season. As these 'free' heat gains are reduced through more efficient lighting, appliances, etc., the space heating requirement increases. Energy reduction benefits that appear to be available through reduced electrical consumption can be offset by about 50%, depending on insulation levels, local climate, etc. The problem is further compounded by the fact that, due to inefficiencies in fossil fuel based space heating systems, more than one unit of fuel must be burned to make up for one unit of reduced 'free' heat, reducing the energy benefit even further [11].

The situation is also complicated by the GHG emission characteristics of the space heating system and the electrical supply system. If the source of electricity is low in GHG emissions (such as the present hydroelectric dominated electrical supply mix in BC and Quebec), increasing the efficiency of electrical equipment in a house with a combustion space heating system can result in a net increase in GHG emissions. At the opposite extreme, in a combustion-generated electrical supply system the effect of reducing electrical consumption through increased efficiency of electrical equipment in the house will have a very large GHG reduction effect (more than 100%) because the efficiency of the space heating system (>60%) is greater than the efficiency of electrical generation (~35%).

Further, calculating GHG emission reduction potential is complicated by the issue of the marginal capacity of the electrical generation system. The generation source that would be shut down first once demand falls, or the new generation source that can be postponed by reducing demand growth may be different from the current generation mix.

The GHG emission benefits of increased electrical equipment efficiency will be greatest in energy-efficient, short heating season, electrically heated houses/apartments in areas with combustion-generated electricity. The benefits will be lowest, or negative, in energy-inefficient, long heating season, combustion heated houses in areas with hydroelectric dominated electrical supply systems (B.C, Quebec, or Manitoba, for example).

As an example, a 20% reduction in electrical energy use for all residential buildings in Canada (total energy use reduced by an average of 4%), would result in reductions in GHG ranging from -3% in Quebec to +8% in the Prairies [21]. These factors must be kept in mind when evaluating the gross energy savings attributed to energy efficient appliances and lighting inside the dwelling. It becomes obvious that broad brush solutions that do not consider regional differences will not be the most successful. This analysis also highlights the need to differentiate between energy reductions and GHG reductions, as they are not always the same.

Other interaction difficulties can result from attempting to add the benefits of multiple energy or GHG emission reduction opportunities. For example, the potential for GHG reduction from window retrofits in the existing stock could not be added directly to the potential from high efficiency furnace retrofits. The potential savings from the furnace retrofit option will be lower with the reduced space heating loads resulting from the higher thermal resistance windows.

3.4.1 Improved End Use Energy Efficiency

This section looks at opportunities for reducing GHG emissions from increased end use energy efficiency of equipment and components within the residential building stock. We first investigate opportunities to reduce energy use and associated GHG emissions of individual components, then of logical packages, or systems. When discussing savings associated with individual components, always keep in mind the interactions between components and the necessity to always think of the 'house as a system'.

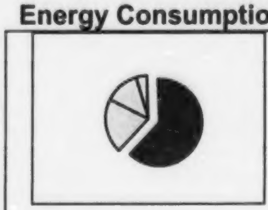
For each category of residential service, we outline the current situation (usually 1996) and then discuss the technical potential for improvement, and any opportunities for integration with other services.

3.4.1.1 Space Heating

In 1996 space heating represented approximately 61% of total end-use energy consumption and 60% of GHG emissions in the entire residential building stock. Generally the proportion of energy used for space heating will be smaller for newer houses and greater for older houses. Energy consumption and GHG emissions from space heating are shown in Table 3.6 along with a breakdown of space heating fuel supply for each housing type[37].

Space heating energy use and GHG emissions are influenced by the energy efficiency of the envelope and by the efficiency of the heating system. The occupant can also have an impact through lowering temperature settings in the winter and increasing them in the summer, closing windows, and by shorter runs of exhaust fans.

Table 3.6 Residential Building Stock Space Heating Energy Consumption and GHG Emissions



	Space Heating Energy (PJ)	Space Heating GHG Emissions (Mt)
1990	790	~43.7
1996	888	~42.4

Space Heating Fuel Supply By Dwelling Type[7]

	Electric	Gas	Oil	Wood
All houses	27.9%	48.9%	13.4%	6.9%
Apartments	58.8%	33.8%	6.7%	

Important Issues Affecting Space Heating:

In low-rise residential dwellings, the walls, ceiling, floor, windows and air-tightness have the largest impacts on energy consumption. Mechanical ventilation in existing housing is minor, however with the requirements of the 1995 National Building Code for increased ventilation in new housing it will become a significant issue.

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[37] Natural Resources Canada, 1993 Survey of Household Energy Use, National Results (also ***Provincial Results*** and *Technical Appendix*), November 1994

In multi unit residential buildings (MURBs), ceilings and floors are much less significant. Even walls are of less importance, since a larger portion of the wall area is occupied by windows.[38] Therefore windows and infiltration are the most significant factors in the envelope heat loss. A 1997 survey of high-rise residential buildings by CMHC[39] found that, on average, heat losses through windows amounted to 31% of the total, air leakage 24% and ventilation 20%. Walls amounted to 16% of total losses, with roof, floor and doors making up the remaining 9%. Similar results were found in a CMHC survey of mid-rise residential buildings[40] - windows and doors 30%, air leakage 23%, mechanical ventilation 16%, walls 16%, roof and floor 15%.

In MURBs with centralised heating systems, there is an opportunity to install high efficiency heating systems, since their incremental cost is spread over a large number of dwellings.

Building Envelope

Building envelope characteristics of existing residential buildings in Canada vary depending on climate, age, and type of dwelling. The characteristics of existing single family houses has been fairly well documented[41] [42] [43], while that of low-rise[44] and high-rise[45] MURBs is much less complete. Table 3.7 below presents a summary of typical residential building envelope characteristics of pre and post 1990 single family detached and attached dwellings.

Table 3.7 Current Residential Building Envelope Characteristics For Single Detached and Attached Buildings[46]

	Existing Houses (pre 1990) [2]	New Houses (after 1990)
Envelope		
Ceiling/Attics	RSI 3.0 to 5.9	RSI 4.7 to 6.9
Walls	RSI 1.4 to 2.4	RSI 2.2 to 3.5
Windows	RSI 0.34	RSI 0.34 to 0.50
Below grade walls	RSI 0.8 to 1.8	RSI 1.3 to 2.3
Below grade floors	RSI 0.0	RSI 0.0 to 0.4
Air tightness	7.9 air changes at 50 Pa	3.0 air changes at 50 Pa

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[38] For example, with 12% of its floor area in windows, a 228 m^2 single detached house will have approximately 10% of its total wall area occupied by windows, however a 10 storey, 120 unit (80 m^2/unit) high-rise will have about 30% of its wall surface occupied by windows.

[39] ***Energy Audits of High-Rise Residential Buildings***, by Scanada, for CMHC, 1997

[40] ***Field Investigations of Indoor Environment and Energy Usage in Mid-Rise Residential Buildings***, August 1997 by Scanada Consultants Ltd./SAR engineering ltd. for CMHC.

[41] ***Residential Retrofit Potential in Canada***, Feb. 96, by SAR engineering ltd. for CMHC

[42] ***1993 Survey of Household Energy Use, National Results*** (also ***Provincial Results*** and *Technical Appendix*), November 1994, for Natural Resources Canada

[43] ***Space Heating Thermal Requirements and Unit Energy Consumption of Canadian Homes in 1993***, by CREEDAC, for NRCan, May 1997

[44] ibid (CMHC mid-rise field investigations)

[45] ibid (CMHC high-rise audits)

[46] ibid (CMHC Retrofit Potential)

Significant improvements in the efficiency of the housing stock envelopes are possible - both in existing housing, through retrofit[47], and in new housing[48] [49] [50] through more stringent energy-related building codes. Reductions in envelope losses of greater than 50% are economically possible.

There is a tremendous potential to 'piggyback' energy efficiency envelope retrofits onto normal retrofits and additions. A number of envelope retrofit options were developed for the CMHC Residential Retrofit Potential in Canada study [2], that are applicable for wood frame construction (single detached through low-rise MURB). These options were analysed on the basis of durability (minimised probability of condensation), thermal resistance, air-tightness and cost.

Table 3.8 outlines a set of possible improved new and retrofit envelope characteristics, which with the opportunities outlined under Mechanical Systems, could lead to the Space Heating Technical Potential shown in Table 3.11.

Table 3.8 Potential Improved Envelope Characteristics by 2010

	Existing Houses[51]	New Houses (near R-2000)
Envelope		
Ceiling/Attics	RSI 9.1 to 9.5	RSI 9.1 to 9.5
Walls	RSI 3.0 to 6.4	RSI 4.0 to 6.4
Windows	RSI 0.50	RSI 0.50
Below grade walls	RSI 2.8 to 3.2	RSI 3.3
Air tightness	5.2 air changes at 50 Pa	2.0 air changes at 50 Pa

Windows

High efficiency windows, such as those used in the Advanced House program, (double or triple glazing, low emission coatings, Argon or Krypton gas fills, and insulated frames and spacers), have been projected to reduce GHG by 2.1 Mt by 2010 and 4.3 Mt by 2020 for both new housing and retrofits[52)

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[47] ***Home Energy Retrofit in Canada, Overview & Opportunities***, March 1994, for Natural Resources Canada, CMHC, Ministry of Natural Resources of Quebec, Ontario Ministry of Environment and Energy, and Hydro Quebec

[48] ***Comparison of R2000 with NBC and MNECH Houses***, October 1994, by Charles Zaloum and Tom Hamlin for Natural Resources Canada

[49] ***R-2000 Monitoring Program Data Processing Results***, March 1995, by Ken Cooper, SAR engineering ltd. for Natural Resources Canada

[50] ***Advanced House Monitoring Comparative Results***, August 1998, by Ken Cooper, SAR engineering ltd. for Natural Resources Canada

[51] These retrofit measures were cost effective for the energy-related costs, based on a 30 year life-cycle cost-benefit of $12/GJ (1989 energy-related retrofit costs versus energy saved).

[52] ***Advanced House Technologies Assessment***, by Scanada Consultants Ltd. for NRCan, February 1996 "Advanced" windows (double glazed, low E, Argon fill), installed in 17.8% of existing houses by 2010; 36.4% by 2020; 53.7% of new houses in 2010; 73.7% in 2020.
"Super-advanced" windows (triple glazed, multiple low E, Argon or Krypton fill), installed in 3.3% of existing houses by 2010; 7.8% by 2020; 7.6% of new houses in 2010; 14.6% in 2020.

Improved comfort should be stressed in promoting these windows, as their thermal resistance is almost as high as the walls in conventional housing, and they are also significantly more air-tight - resulting in reduced cold drafts. The higher insulation levels on the glass and the frames results in reduced condensation, which in turn reduces damage to the frame and walls, and reduces mould growth and its adverse health effects.

Space Heating Equipment

The efficiency of new residential space heating equipment has increased significantly over the last few years. The average Annual Fuel Utilisation Efficiency (AFUE) of new gas space heating equipment increased from 71%, in 1990 to 83% in 1996. This is a result of a move away from conventional (annual efficiency of 60% to 65%) furnaces and boilers, which are no longer sold in Canada, to mid-efficiency (78% to 83% annual efficiency) and high-efficiency units (90% or more). This has led to an increase in the average efficiency of the entire gas-heated stock from 64% in 1990 to 66% in 1996[53]. The high end of currently available furnaces are condensing furnaces with about 94% efficiencies.

Similar improvements have occurred in oil heating equipment. Average new equipment efficiencies increased from 63% in 1990 to 68% in 1996. This has resulted in an increase in the stock efficiency from 60% in 1990 to 61% in 1996[54]. The high end of currently available oil condensing furnaces can achieve about 94% AFUE as well.

These slow changes in stock efficiencies illustrate the slow impact of even significant changes in the efficiency of new equipment, when the turnover rate is relatively long. In 1996, there were 90,100 Canadian shipments of mid-efficiency natural gas furnaces, and 69,500 of high-efficiency furnaces.[55]. At that rate, it would take over 18 years to replace all of the existing natural gas furnaces in single detached housing alone. This would, however reduce space heating energy use in the existing stock (assuming no other changes or growth in the stock) by about 97 PJ and GHG by about 4.8 Mt, which is greater than 10% of total 1996 residential direct emissions.[56]

Air Source Heat Pumps

There is a potential to reduce electrical space heating requirements significantly through the use of heat pump technology, either air source or ground/water source (see section 3.4.4.1 renewable energy for ground source heat pumps). Air source heat pumps transfer the heat in the outside air into a building in winter, and transfer the heat in the building to the outside air in the summer, using the same principle as a refrigerator. The heat obtained from the air is much greater than the electrical energy that is required to drive the various components of the system. Typical air cooled heat pumps have coefficient of performance (COP) ratings of approximately 3.2 to 3.5, resulting in less than one third of the energy consumption of electric resistance heating.

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[53] ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan

[54] ibid

[55] ibid

[56] Assuming that natural gas space heating energy usage is 434 PJ in 1996 (48.9% of 888 PJ, Table 3.6) and that average furnace efficiency changes from 66% in 1996 [4] to about 85% (approximately equal numbers of mid and high efficiency units).

Air source heat pumps are well suited to moderate climates, but they do not operate efficiently when the outdoor air temperature drops below -10C. At lower temperatures there is little heat left to be extracted from the air and electric resistance supplementary heating is used. This results in relatively low coefficient of performance (COP) ratings during the peak heating season. One study[57] monitored a COP of only 1.35 during the Halifax heating season. GHG emissions from this type of system, in a region with combustion dominated electrical generation (such as the Maritimes or Prairies), would be higher than with an oil or gas furnace, but significantly lower in regions with low carbon content electricity.

A factor that could affect market penetration of all types of efficient space heating technology is that, as the envelope heat losses decrease, it becomes increasingly difficult to cost-justify efficient, but expensive, complex heating and control systems. There were numerous examples of this that became apparent in the Advanced House program[58]. This is another justification for increased housing density, and/or for using community-heating systems, so that the cost of the efficient heating system can be spread over a number of units. Another method to reduce costs is with the integration of several functions - space and water heating, or space heating and ventilation heat recovery, for example[59] [60].

Heating System Controls

Programmable thermostats are used in about 18% of all single detached/attached houses[61]. Night setback controls allow for some space heating energy reduction by lowering the average temperature over a 24 hour period. Line voltage thermostats provide better space heating control than conventional thermostats and can result in significant energy savings in electrically heated homes.

As residential Heating, Ventilation, and Air Conditioning (HVAC) systems become increasingly complex, the need is growing for more sophisticated control, monitoring and diagnostic control systems[62] [63]. These sophisticated monitoring/control systems can ensure that the occupants are advised of energy use beyond the norm and of equipment malfunctions.

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[57] ***Investigation of the Thermal Performance and Economic Feasibility of R-2000 Houses Equipped with Air Source Heat Pumps***, by TUNS, for NRCan, November 1991

[58] ibid

[59] ibid

[60] ***Advanced House Technologies Assessment***, by Scanada Consultants Ltd. for NRCan, February 1996

[61] ***1993 Survey of Household Energy Use, National Results*** (also ***Provincial Results*** and *Technical Appendix*), for NRCan, November 1994

[62] ***Residential HVAC Controller***, in progress, by L. Bertsch of Horizon Technologies Inc. for NRCan

[63] ***Residential HVAC Controller Sensitivity Analysis,*** in progress, by SAR engineering ltd. for NRCan

Motors

Improvements can be made in the efficiency of motors used for furnace fans, ventilation fans, elevators, and other equipment. Permanent split capacitor motors are typically about 44% efficient, compared with the 30% to 35% efficiency of conventional split phase AC motors. Electrically Commutated Motors (ECM) are typically 70% to 80% efficient, more than double that of conventional motors. Implementing the use of ECM motors, in new and retrofitted furnaces alone, has been projected to reduce GHG emissions by 81 KT per year by 2010 and 396 kT per year by 2020[64].

Gas fireplaces

New gas fireplaces typically have efficiencies in the range of about 50%. With forced air heat recovery, and direct vent combustion air supply and doors, efficiency can be improved to as high as about 70%.

Humidifiers

Humidification was used in 24% of houses in 1993[65] In a well-designed, energy-efficient dwelling, humidification requirements decrease, relative to conventional housing, since air change rates are generally reduced during the coldest periods (when the outside air is driest).

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[64] ***Advanced House Technologies Assessment***, by Scanada Consultants Ltd. for NRCan, February 1996 Assuming penetration rates of up to 77% in new housing and up to 2% per year of existing housing stock (2020).

[65] ***1993 Survey of Household Energy Use, National Results***, for NRCan, November 1994

3.4.1.2 Ventilation Systems

Ventilation is necessary in modern buildings to ensure adequate indoor air quality and reduce humidity levels. The necessity for controlled ventilation has increased over time as building envelopes have been tightened to reduce infiltration related energy consumption, and as potentially toxic emissions from materials used in construction and furnishings have increased. Control of materials used in construction and furnishings and/or sealing of surfaces can reduce the rate of emissions and potentially reduce the building material related ventilation requirements in buildings. Ventilation will still be required to reduce humidity and carbon dioxide levels and odours due to occupancy.

Table 3.9 shows a few characteristics of ventilation use in the current residential stock.

Table 3.9 - Current Residential Ventilation Practice

Single-Detached/Attached	
Types	**Characteristics**
Exhaust fans	Bathroom, Kitchen - intermittent use
Continuous ventilation	Relatively rare
Heat recovery ventilators	Mostly in R-2000; some in Ontario new houses, 90% of new homes in Halifax, common in Maritimes
Multi-Unit Residential Buildings	
Types	**Characteristics**
Corridor make-up air	Most common
Heat recovery ventilator	Relatively rare

There is currently very little mechanical ventilation in the existing single detached or attached housing stock in Canada. Therefore, as the use of ventilation increases as a result of new National Building Code requirements and envelope tightening in retrofits, energy use and associated indirect GHG emissions could increase significantly. As an example, a 40 W exhaust fan operating continuously without heat recovery, in every existing single family dwelling, would cause a nation-wide increase of about 131 kT/year of GHG emissions.

Multi unit mid and high rise residential buildings generally have corridor ventilation supply systems that are large consumers of energy, and usually do not use heat recovery. Both the air supply and distribution in these buildings depends on weather, on building configuration and airflow paths, and on mechanical system operation. The complexity of the issue, and lack of research into airflow within these buildings, has resulted in little guidance for designers. As a result these systems are generally not optimally designed for either ventilation or energy efficiency. A CMHC survey of mid-rise MURBs[66] found that proper distribution of ventilation air is not occurring in many buildings - while capacity and measured air flow rates into the corridors was adequate, actual ventilation flow rates into the apartments was negligible in most buildings and insufficient in the rest.

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[66] ***Field Investigations of Indoor Environment and Energy Usage in Mid-Rise Residential Buildings***, August 1997 by Scanada Consultants Ltd./SAR engineering ltd. for CMHC

Heat Recovery Ventilators (HRV's)

Heat recovery ventilators can be used to recover 40% to 60% of the heat normally lost in ventilation air. The recovered heat can be used to preheat ventilation air or to preheat domestic hot water. Typically, heat recovery efficiencies are 10% to 20% less than rated due to unbalanced air flows, blocked filters or intakes, etc.[67] [68].

Latent heat HRV's can recover moisture from the exhaust air stream and therefore reduce humidification requirements. Units in two Advanced Houses had difficulties during winter operation, however[69].

Heat pumps have been used to recover heat from ventilation the exhaust air flow to either preheat ventilation air or to provide domestic water preheating[70].

There is a potential to maximise efficiencies of heat recovery equipment through the use of diagnostic controllers that would provide feedback to the occupant and service technician regarding malfunctions in the equipment[71]. For example, detection of a partially blocked intake or filter that reduced HRV supply air flow by only 7% would decrease the HRV efficiency and result in about a 1.2% increase in space heating[72].

Advanced controllers can also provide ventilation as required, using sensors to measure indoor air pollutants such as CO2. Paybacks for this type of technology would be greatest for non-heat recovery systems.

Overall ventilation rates can be reduced in the multi-zone distribution systems which are used in larger MURBs if occupancy sensors (often used for security reasons) are integrated into a control system to deliver fresh air primarily to occupied zones[73].

Table 3.10 - Potential for Residential Ventilation Improvements

Types	Characteristics
Exhaust fans	more efficient motors, controls
Balanced fans	
Heat Recovery Ventilators	40% to 60% heat recovery efficiency
Heat pump	COP 2 to 3
Advanced Controllers	Diagnostic controllers ensure optimal operation of HVAC systems

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[67] ***R-2000 Monitoring Program Data Processing Results***, SAR engineering ltd. for NRCan, March 1995

[68] ***Advanced House Monitoring Comparative Results***, by SAR engineering ltd. for NRCan, August 1998

[69] ibid

[70] ibid

[71] ***Residential HVAC Controller***, in progress, by L. Bertsch of Horizon Technologies Inc. for NRCan

[72] ***Residential HVAC Controller Sensitivity Analysis,*** in progress, by SAR engineering ltd. for NRCan

[73] ibid (Advanced House Monitoring)

Space Heating and Ventilation Technical Potential

If we apply the improvements to the building envelope, the high efficiency heating systems, efficient motors, and ventilation heat recovery energy equipment discussed in the previous section to the entire 1996 residential building stock, it is possible to reduce residential space heating energy and GHG emissions significantly. Space heating energy can be reduced to about 618 PJ from the 888 PJ used in 1996, and the 790 PJ used in 1990. GHG emissions can be reduced to about 30.4 Mt from the 43.7 Mt in 1996 and 42.4 Mt in 1990 - a reduction of 38% from the 1990 levels. These reductions are shown below in Table 3.11.

Table 3.11 Space Heating and Ventilation Technical Potential[74]

	1990	1996	2010
Energy	**790 PJ**	**888 PJ**	**~618 PJ**
GHG (CO_2 equivalent)	**42.4 Mt**	**43.7 Mt**	**~30.4 Mt**

3.4.1.3 Space Cooling

Characteristics of current space cooling practice, energy consumption, and resulting GHG emissions for the entire residential building stock are presented below in Table 3.12. Space cooling represents approximately 0.4% of the total residential end-use energy consumption[75]

The highest occurrence of air-conditioned dwellings in Manitoba (49.7%), with Ontario next (46.5%), then Saskatchewan (36.5%). Occurrence in all other provinces was 8% or less[76].

Table 3.12 Space Cooling - Current Practice

Space cooling represents approximately 0.4% of the total residential end-use energy consumption		
	1990	**1996**

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[74] Space heating technical potential assuming 16% increase in the housing stock:
Single-detached/attached: 100% of current existing houses retrofitted to close to insulation levels 30% greater than the MNECH and condensing gas/oil integrated space/DHW systems, heat recovery ventilation. New housing in 2010 built to energy efficiency levels approximately 37% better than in 1990 (approaching R-2000).
MURB: retrofit of 100% of existing apartments with high efficiency windows and air-tightening, heat recovery on ventilation, condensing gas/oil or GSHP heating systems. New units approaching C2000 standards by 2010.

[75] ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan

[76] ***1993 Survey of Household Energy Use, National Results*** (also ***Provincial Results*** and *Technical Appendix*), for NRCan, November 1994

Energy	**5.8 PJ**		
GHG Emissions	**0.3 Mt**		

Cooling, by % of dwellings, in 1993[77]	**Air Conditioning**	**Central or Heat Pump**	**Window or Room**
Houses	28.6%	18.9%	9.7%
Apartments	20.8%	7.3%	13.5%

There is very little published information on cooling requirements in MURBs. Sample sizes in the 1993 Survey of Household Energy Use are too small for a detailed breakdown, the eight mid-rise MURBs in the CMHC Field Investigations of Indoor Environment and Energy Usage in Mid-Rise Residential Buildings did not have cooling systems, and the CMHC Energy Audits of High-Rise Residential Buildings only covered the period from September to May (0.2% to 12.8% of energy use for cooling outside the cooling season).

Most air conditioners are used infrequently. Over 50% of installed units were used a few days per year at most.[78]. Given the fairly large installed base of air conditioning units, there is a potential for increased usage in a globally warming climate. While the efficiency of air conditioning equipment is increasing, these improvements will likely be overshadowed by increased market penetration and usage.

Other cooling system options have been explored in some houses through the Advanced House Program. In the Saskatchewan Advanced house, a fluid was cooled by pumping it through coils under the basement floor slab and then used to cool the house by passing the fluid through radiant ceiling panels. This system was able to provide a maximum of 1.8 kW of cooling and a measured average COP of 26 in July and 32 in August[79] This type of system is only suited to new houses.

The B.C. Advanced house used its "CEBUS" control system to switch its continuous circulation fan to 100% outside air whenever the house required cooling and the outside air temperature was cooler than the inside. This system required only an inlet duct, motorised damper, and the smart controller[80] to provide a maximum of 3.6 kW of cooling and a total of 1124 kWh of cooling in the months of July/August, with an average COP of 15.6. This type of system could be used on new or existing houses with forced air heating.

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[77] ibid (1993 Survey…)

[78] ibid

[79] ***Advanced House Monitoring Comparative Results***, by SAR engineering ltd. for NRCan, August 1998

[80] The system also had a two speed fan, for more cooling capacity, and an electronically commutated motor (ECM) for greater efficiency of operation. With a more sophisticated controller to ensure adequate distribution of ventilation, the HRV could be shut off during periods of cooling for even greater energy savings (COP ~61). ***B.C. Advanced House Monitoring Results***, by SAR engineering ltd. for NRCan, August 1998

A prediction of the technical potential for space cooling is difficult to make because of the large influences of penetration rates and changes in usage.

3.4.1.4 Water Heating

A breakdown of current residential stock energy consumption, GHG emissions, and fuel types is presented below in Table 3.14. Heating water for domestic use accounted for approximately 22% of residential energy use in 1996[81], or about 299 PJ. In new energy efficient homes this percentage is much higher than 22%. The majority of individual water heaters use electricity (57%), while 38% use gas.

Table 3.14 Domestic Hot Water (DHW) - Current Practice

Heating water for domestic use accounted for approximately 22% of residential energy use in 1996

	1990	1996
Energy	**262 PJ**	**308 PJ**
GHG Emissions	**~13.7 Mt**	**~16.1 Mt**

Water heating fuel type; by % of dwellings in 1993[82]:

	Electricity	Gas	Oil	Other	
All houses - individual systems	50%	42.4%	3.6%	1.1%	3% shared systems
Apartments - individual systems	33%	1.8%	0.1%	0.1%	65% shared systems

Currently, electric water heaters have an efficiency of approximately 93%, while natural gas and oil-heated units are much lower at about 50% to 60% efficiency. The average new natural gas water heater sold has an energy factor rating of 54%. Direct vent natural gas domestic water heaters with electronic ignition and induced draft fans that achieve energy factor efficiencies of 60% are in the field test stage. Heat pumps equipped with desuperheaters for hot water heating can provide hot water using one quarter or less of the energy required for electric hot water heaters.

In all houses water-efficient strategies can be employed to reduce hot water demand. These include low flow showerheads and faucets. In some parts of the country these already have a fairly high penetration rate (low flow faucets are mandated in new construction in Vancouver, for example).

Options for reducing hot water energy use include:

- more efficient water heaters,
- use of highly efficient heat pumps with de-superheaters for providing hot water.
- installing insulated jackets and heat traps on water heaters,
- lowing water temperature on water heaters,
- integration of the domestic hot water supply with much higher efficiency space heating systems such as condensing gas or oil boilers, or electric ground source heat pumps.,
- use of front loading/horizontal access clothes washers,

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[81] ***Canada's Energy Outlook 1996-2020***, 1997, by/for Natural Resources Canada

[82] ***1993 Survey of Household Energy Use, National Results*** (also ***Provincial Results*** and *Technical Appendix*), for NRCan, November 1994

- grey water heat recovery, which can be used to recapture up to 42% of the energy in the water[83], and/or
- alternative sources of energy such as solar pre-heating, which can provide approximately 50% of the DHW energy requirement.

In 65% of multi unit residential buildings domestic hot water is provided by systems shared amongst multiple dwellings. To ensure that hot water is delivered quickly to each apartment, these shared systems often use a pumped continuous circulation system. Unless the hot water pipes are thoroughly insulated, heat losses to the space can be as large as the water heating demand. With their relatively low envelope heat loss and high occupant heat gains, MURBs have a shorter 'heating season' than single family dwellings, so less of this 'free heat' is useful. Even worse, the pipe heat losses become part of the cooling load in air-conditioned buildings.

An efficient option for MURBs could be combination systems that use a shared boiler that provides preheating of DHW up to 20C to 25C[84], and individual heaters in each unit. Piping heat losses and the requirement for insulation would be eliminated. The shared system could be an efficient boiler alone, or in combination with a low solar fraction solar DHW system.

Energy use for domestic hot water could be reduced from 308 PJ to about 254 PJ (13.4 Mt GHG) as shown in Table 3.15 if all gas and oil heating units were replaced with high efficiency stand-alone or integrated units. Further reductions would be possible with ground source heat pump systems. Energy use could be even further reduced to about 137 PJ (7.2 Mt GHG) through the use of active solar water heating systems or grey water heat recovery (in addition to using high efficiency heating systems) in all dwellings by 2010.

Table 3.15 Domestic Hot Water (DHW) - Technical Potential

	1990 Energy	1996 Energy	2010 Energy
Efficient DHW Heaters	262 PJ	308 PJ	254 PJ
Solar/Heat Recovery			137 PJ
	1990 GHG Emissions	**1996 GHG Emissions**	**2010 GHG Emissions**
Efficient DHW Heaters	~13.7 Mt	~16.1 Mt	~13.4 Mt
Solar/Heat Recovery			~7.2 Mt

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[83] ***Design and Analysis of a Residential Greywater Heat Recovery System***, by Proskiw Egineering Ltd. for NRCan, October 1995

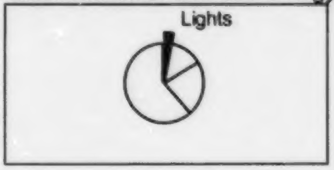
[84] Note that, in winter in most of Canada, inlet water line temperatures are as low as 3C to 5C, so preheating to 25C constitutes about 40% of the required DHW heating requirement, with a final temperature of 50C to 55C. The shared component would be less in late summer, when inlet water temperatures reach 15C to 17C.

3.4.1.5 Lighting

In 1996 lighting represented approximately 4.1% of total end-use energy consumption in the entire residential building stock. Energy consumption and GHG emissions from lighting are shown in Table 3.16 below.

Table 3.16 Lighting - Current Practice

Lighting represents approximately 4.1% of the total residential end-use energy consumption[85].



	1990	1996
Energy		**59 PJ**
GHG Emissions		**3.0 Mt**

Incandescent lighting, which is only approximately 6% efficient, is the predominant form of residential lighting. It is used for almost 90% of the average 27 light "bulbs" per dwelling.[86]. More efficient fluorescent fixtures which are about 20% to 25% efficient accounted for just over 8% of average lighting. The remaining 2% were primarily Halogen bulbs. In larger dwellings there is a larger percentage of use of halogen (up to 3%) and fluorescent lighting(up to 11%).

In all dwellings, the trend is towards an increasing number of light bulbs and fixtures. The average number of bulbs per dwelling is 22.9 for those constructed before 1941, and 34.8 for dwellings built in 1983 and later.. This trend applies to both indoor and outdoor lighting. As one would expect, the number of bulbs/fixtures increases with size of dwelling. Numbers range from a total of 13.7 for dwellings less than about 56 square meters heated area (probably mostly apartments) to 49.6 for dwellings of more than 232 square meters heated area (not including basements)[87].

The turnover rate for incandescent bulbs is typically less than one year, however changes in fixtures is much longer. It would therefore be reasonable to promote conversion of incandescent fixtures, wherever feasible, to commercial T8 technology (32 W per lamp), with electronic ballasts, rather than conventional fluorescent lighting. Fluorescent fixtures can also incorporate highly reflective surfaces to increase their output.

Also, fixture or replacement bulb design must be modified for compact fluorescent bulbs to be used on a wide scale, since most existing fixtures will not accommodate them.

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[85] ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan

[86] ***1993 Survey of Household Energy Use, National Results*** (also ***Provincial Results*** and *Technical Appendix*), for NRCan, November 1994

[87] ibid

Natural lighting could supplement artificial lighting during the day, if design techniques were borrowed from the commercial sector. Also, as windows become more efficient, increased glazed areas could result in lower day-time lighting energy use[88].

Lighting controls, such as motion sensors for outdoor lights are relatively common, but, their application should be further encouraged. A 'smart' lighting system inside the house could use existing intruder alarm motion sensors to turn lights off in empty rooms. Also, individual light switches with motion sensing capability already exist.

The Technical Potential for energy and GHG reduction using more efficient lighting is shown below in Table 3.17. The table shows total reduction of 36 PJ electricity and 2.0 Mt GHG by 2010. However, net energy reductions, after accounting for increases in space heating requirements, will be about half these values. Reductions in GHG emissions will be similar to the reductions in energy, but will depend regionally on the mix of electrical generation.

Table 3.17 Lighting - Technical Potential[89]

	1990	1996	2010
Energy		**59 PJ**	**~23 PJ**
GHG (CO_2 equivalent)		**3.2 Mt**	**~1.2 Mt**

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[88] Note, however, that simply increasing glazed areas does not result in reduced artificial lighting - in fact, the opposite can occur if poor design results in high lighting contrast ratios within a room.

[89] The energy and GHG values are based on 100% implementation of lighting technology with an efficiency of about 25% (equivalent to current fluorescent lights), and a projected generation rate of GHG emissions of 50.8 tonnes GHG per TJ of electrical energy [17], and a 16% increase in housing stock 1996 to 2010.

3.4.1.6 Appliances and Other Equipment

In 1996 appliance and plug load use represented approximately 13.3% of total end-use energy consumption in the entire residential building stock. Energy consumption and GHG emissions from appliances in 1990 and 1996 are shown in Table 3.17 below.

Table 3.17 Appliances & other equipment - Current Practice

Appliances, and plug loads represent approximately 13.3% of the total residential end-use energy consumption[90].

	1990	1996
Energy	**184 PJ**	**192 PJ**
GHG Emissions	**~10.4 Mt**	**~9.7 Mt**

This is an area of strong user interaction, so that increased efficiency does not always translate into expected savings. Monitoring has shown energy use for lighting and appliances higher than expected in several programs[91] [92]. Whole house usage patterns need to be analysed and updated. More efficient, but inexpensive new appliances such as VCRs and TVs may simply result in the homeowner using several of them, wiping out some or all of the potential reductions in energy use.

Load management of the large energy uses within the home can reduce peak energy demands. Reduced peak demand can enable electrical generation facilities to avoid bringing higher carbon emitting fossil-fuel generation systems on line.

Refrigerators and Freezers

The most common type of new refrigerator is an Energuide Type 3, automatic defrost, with or without top freezers, with a volume from 15.5 to 18.5 cubic feet. Energuide ratings for this type of refrigerator have declined from 1865 kWh to 661 kWh per year from 1979 to 1995 and then held constant for the last three years. If the long term trend holds, Energuide ratings should decrease to about 287 kWh per year by 2010 (an average of only 33W)[93].

After accounting for households with more than one refrigerator (19% in 1997), and the average age of refrigerators, average energy use for refrigerators is presently (1998) about 1,272 kWh per year. Refrigerator energy use is projected to decrease to about 637 kWh per year in 2010, a reduction of 50% in indirect energy use[94].

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[90] ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan

[91] ***R-2000 Monitoring Program Data Processing Results***, SAR engineering ltd. for NRCan, March 1995

[92] ***Advanced House Monitoring Comparative Results***, by SAR engineering ltd. for NRCan, August 1998

[93] ***Energy Efficiency and Penetration Rates of Appliances in Canadian Houses*** by J. Gusdorf, NRCan Buildings Group, August, 1998

[94] ibid

The most popular freezers are chest type of 9.5 to 11.5 cubic feet capacity which are currently used in about 58% of households. The average freezer energy use dropped from 995 kWh per year in 1980 to 550 kWh per year in 1990, then more slowly to 377 kWh per year in 1998. Using 1980 to present trends, NRCan projections predict energy usage of only 144 kWh per year (16W average) by 2010. However, it can be argued that the trend since 1990 is more probable, and would result in an energy usage in 2010 of about 275 kWh per year (31 W average)[95]. Accounting for average energy use and penetration rates yields a 54% reduction from 308 kWh per year in 1998 to 141 kWh per year in 2010.

Net energy reductions, after accounting reduced space heating requirements, will be about half these values, and net reductions in GHG will depend on the heating systems and the regional mix of electrical generation.

Other methods of preserving food should also be explored as alternatives to refrigeration and freezing.

Food Preparation - Stoves and Microwave Ovens

Typical cooking ranges have shown virtually no change in Energuide energy use ratings (~790 kWh/y) over the last twenty years and no significant improvements are projected[96].

Sealed combustion natural gas ranges were used in several of the Advanced Houses, with mixed results. Heating efficiency is claimed to be 24% higher than conventional gas ranges, however the measured 100 to 250 kWh per year electrical energy use (for combustion air fan, igniters, etc.) could eliminate most of that saving[97] [98]. Slow heating rates (comparable to electric ranges) and problems with breakage of the glass top could limit current acceptance.

Approximately 90% of all households have microwave ovens, which theoretically should use much less energy for cooking because of their higher efficiency. Aesthetic factors limit their use, however, since they cannot normally 'brown' the food (unless combined with convection or other conventional cooking systems). Microwave ovens may actually result in an increase in energy use if used excessively for re-heating and defrosting.

Dishwashers

A 56% reduction in Energuide rating in new dishwashers has occurred between 1981 and 1998, from 1412 to 624 kWh/year. Hot water use, which is responsible for about 80% of the energy used by dishwashers, has decreased from about 43.7 L to 27.0 L per load, which is the main contributor to this increased efficiency. Based on this historical decline, NRCan projects that new units will use an average of 375 kWh/year (which includes 23.4 L of hot water per load) by 2010. Combined with penetration rates of 49% in 1997 and a projected penetration of 62% by 2010, the average energy use per household is projected to drop from 438 kWh per year in 1998 to 305 kWh per year in 2010[99].

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[95] ibid (However, long term projections may not be linear since there are technological limits to how little energy is needed by physical processes).

[96] ibid

[97] ***Advanced House Monitoring Comparative Results***, by SAR engineering ltd. for NRCan, August 1998

[98] ***Advanced House Technologies Assessment***, by Scanada Consultants Ltd. for NRCan, 1996

Note that the hot water portion of these figures is also accounted for in the DHW technical potential figures presented previously, and that dishwasher energy use predictions will also be affected by the average efficiency of the DHW equipment in use in 2010. Changes in hot water use have a relatively minor affect on space heating requirements since most of the heat added to the water leaves the building.

Clothes Washers

EnerGuide ratings for new clothes washers, which also include energy for hot water, declined from about 1335 kWh per year in 1981 to 905 kWh per year in 1998. This decrease occurred in spite of an 11% increase in average volume. NRCan projections based on historical changes in energy efficiency would result in a rating of 743 kWh per year by 2010, which when coupled with a penetration of 80% in 1997 and 81% in 2010 would result in a per household decline from 896 to 693 kWh per year[100].

Front-loading washing machines have a greater potential for energy reductions since they use 40% less hot water and over 60% less energy than top-loading models (EnerGuide ratings of about 300 kWh per year, including hot water). Currently the price of these units is about 50% higher than conventional models[101]. Note again that the hot water portion of these figures is accounted for in the section on DHW, and will also be affected by the average efficiency of the DHW equipment in use in 2010.

Clothes Dryers

Average EnerGuide ratings for clothes dryers fell from 1186 kWh per year in 1982 to 923 kWh per year in 1998. NRCan projects a further 25% decrease to 696 kWh per year by 2010[102].

In 1976, 55% of houses had dryers, increasing to 77% in 1997. Natural gas-fired dryers accounted for 4.5% of all clothes dryers in 1997. Penetration rates are projected to be about 80% by 2010 (98% of all clothes washers).

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[99] ***Energy Efficiency and Penetration Rates of Appliances in Canadian Houses*** by J. Gusdorf, NRCan Buildings Group, August, 1998

[100] ibid

[101] ibid

[102] ***Energy Efficiency and Penetration Rates of Appliances in Canadian Houses*** by J. Gusdorf, NRCan Buildings Group, August, 1998

Combining energy use and penetration rates, the average energy use will drop from 775 kWh per year in 1998 to 644 kWh per year in 2010.

Operation of dryers effect space heating energy use in two ways. Heat from the dryer reduces space heating requirements by a small amount, but more significantly, the dryer exhausts air from the house while it is operating. This unbalanced air flow increases infiltration into the house. Heat recovery on the dryer exhaust is possible. The Manitoba Advanced house used a separate heat recovery ventilator on the dryer exhaust, but had difficulties with its operation.

Miscellaneous electrical equipment

Minor appliances (everything not included under space conditioning, hot water, lighting or major appliances) use about 1300 kWh per dwelling per year at present. Energy use per dwelling for miscellaneous electrical equipment is projected to increase by about 15% by 2010.[103]

Some types of these equipment have quite significant energy use. Water bed heaters, which are present in about 13% of houses, use about 3.4 kWh per day. This is more than the average cooking range. Aquariums (in 4% of houses) use about 1.5 kWh per day and the average hot tub (7% of houses) uses about 6.3 kWh per day[104].

Audio/visual, Entertainment systems, Computers, etc.

Electronic equipment is improving in efficiency, however increasing numbers per residence (multiple VCRs, home computers, etc.) and large screen TVs are resulting in overall increased energy consumption. Home offices increase residential consumption, however the net effect is probably reduced energy consumption due to reduced commercial and transportation energy use. Much of this equipment has small standby energy use (picture tubes emitters, clocks, etc.).

Outdoor Equipment

The category of outdoor equipment includes a wide range of items ranging from electrical power tools, electrical or gasoline mowers, security/convenience lighting, and vehicle warmers (engine block and vehicle interior).

Manual yard tools (mowers, clippers, etc.) would reduce outside energy use, while electrical yard tools would, in most cases, reduce GHG when compared to combustion types, due to the low efficiency levels of combustion equipment.

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[103] ibid

[104] ***Space Heating Thermal Requirements and Unit Energy Consumption of Canadian Homes in 1993***, by CREEDAC, for NRCan, May 1997

Energy use due to exterior lighting can be greatly reduced through the use of photocell/motion sensors. Compact fluorescent exterior lights can be used in mild climates such as Vancouver or Victoria.

Vehicle warmers and block heaters can consume significant amounts of electricity (the latter estimated to use 0.68 kWh per day at 32% of dwellings[105]), particularly if left on too long. Timers and/or remote controls can reduce excessive use.

Projections of the technical potential for reducing energy and GHG emissions from appliance are shown in Table 3.18. Estimates are based on an assumed reduction in energy use of 28% by major appliances, an increase of about 15% in energy use by minor appliances, resulting in a per household reduction of 19% from 1998 to 2010 (energy use by the major appliances was relatively flat from 1996 to 1998). With a projected increase in the number of households of about 16% by 2010, the overall energy reduction is only about 3% to 4%. Accounting for increased space heating results in a net energy reduction of only about 2%[106].

Table 3.18 Appliances & other equipment - Technical Potential

	1990	1996	2010
Energy	**184 PJ**	**192 PJ**	**~185 PJ**
GHG Emissions	**10.4 Mt**	**9.7 Mt**	**~9.4 Mt**

Note: These figures do not account for changes in space heating

Compared to 1990, energy use for appliances is relatively flat, increasing by 8 PJ between 1990 and 1996[107]. Energy use is projected to decrease by about 7 PJ between 1996 and 2010. The reduction in GHG emissions of about 1.0 Mt 10.4 Mt to 9.4 Mt) is due to the change in generation efficiency and mix (56.6 Mt of GHG per PJ in 1990, projected to decrease to 50.8 Mt GHG per PJ in 2010[108]).

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[105] ***Space Heating Thermal Requirements & Unit Energy Consumption in 1993***, by CREEDAC. for NRCan

[106] ***Energy Efficiency and Penetration Rates of Appliances in Canadian Houses*** by J. Gusdorf, NRCan Buildings Group, August, 1998

[107] ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan

[108] ***Background Information on Greenhouse Gas Emissions from Canadian Housing*** by J. Gusdorf, NRCan Buildings Group, October, 1998

3.4.1.7 Metering of Multi Unit Residential Dwelling Units

Without co-operation of tenants in multi-unit residential housing projects, energy conservation measures are nearly fruitless. In many rental apartment buildings, however, central heating and cooling equipment is used with no metering or cost allocation to individual units. Energy cost allocation to individual dwelling units has been shown to be an effective way to influence the behaviour of multi unit residential building tenants, typically reducing energy use by 15% or more.[109] While metering of energy consumption to individual units is one method, variations in exposed surface area, wind and stack effects and so on cause large variations in energy consumption of individual units and may therefore be inequitable. Another choice is energy cost allocation systems that monitor and allocate costs based on the set point of individual dwelling unit thermostats. When residents are aware of consumption and cost, and realise that they can save money with a lower average set point they keep the windows closed and turn down their thermostats.

Metering or energy cost allocation for hot water consumption in multi-unit residential buildings would have a similar effect on hot water consumption. Thermal energy meters are readily available that can meter the energy of hot water space and DHW consumption. Their price is, however, in the range of approximately $400.

Metering of electrical consumption in all multi-unit residential buildings is a relatively simple task that could be used to reduce energy consumption through behavioural change, and is particularly important for electrically-heated buildings.

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[109] Hewett et al, Heating Cost Allocation in Multi-family Buildings: Energy Savings and Implementation Standards, ASHRAE Transactions 95 (1), 1989.

3.4.2 Whole Building Improvements

As discussed in the Introduction to section 3.4, changes inside the conditioned building envelope interact with one another. The result of some interactions reduces overall benefits. For example, reducing lighting energy use results in an increase in the space heating energy requirement. However, some interactions result in an amplification of the effect - reducing lighting energy use also reduces energy required for cooling, for example. The result of these interactions is that an accurate assessment of the effect of several changes can only be made by simulating the dwellings at the whole building level, not by adding the individual effects.

These energy interactions are only two of the "house as a system" factors to be considered. Others include:

Increasing air-tightness

- reduces energy use due to infiltration,
- reduces indoor air quality (unless ventilation is increased),
- reduces drafts in winter and
- reduces the likelihood of condensation in the structure,

Increasing insulation levels (ceilings, walls, etc.) -

- reduces energy use for space heating by an amount greater than the reduction in total losses (both the magnitude of the losses and the length of the heating season are reduced),
- increases the risk of condensation in the structure (unless air tightness is addressed), and
- increases comfort levels due to higher surface temperatures, however also may increase the amount of overheating due to solar and/or internal heat gains.

Increasing the energy efficiency of windows -

- reduces energy use for space heating by an amount greater than the reduction in total losses (both the magnitude of the losses and the length of the heating season are reduced),
- reduces the risk of condensation on the glazing and frame (enhancing IAQ due to reduced amounts of mold),
- may reduce the total solar gains (if southward facing) - depending on the method used to increase the energy efficiency (additional glazings and low emissivity coatings reduce solar heat gain). Overheating due to solar heat gain will increase or decrease, depending on the clear day energy balances (dwelling heat losses, internal heat gains and solar heat gains)

Installing/using a fireplace, can -

- increase infiltration due to the air flow up the chimney (it functions like a "natural exhaust fan"),

- cause IAQ problems due to back-drafting when exhaust fans operate (particularly some of the more powerful range hood fans),
- cause house fires if creosote is allowed to build up (slow "burns")

Switching from a combustion furnace and water heater to electricity

- may reduce or increase GHG emissions - depending on the method of electrical generation and the efficiency of the original heating system,
- reduces infiltration due to elimination of the chimney,
- may cause condensation in the structure due to lowering of the neutral pressure plane in the dwelling. In single-detached/attached housing, the neutral pressure plane is near the ceiling during operation of the combustion furnace, with dry air flowing in virtually everywhere. With electrical heating, the neutral pressure plane is approximately midway up the building - resulting in an outward flow of moist air through the upper half of the structure. Attention to air-tightening can alleviate this problem.
- may increase GHG if the electricity is generated in a combustion dominated electrical generation system

For these reasons holistic 'house as a system' programs are necessary to achieve significant results without causing undesirable side effects. We review the effect of several existing programs that attempt to promote this whole building approach.

Some programs aimed at improving energy efficiency in the residential sector have taken a piecemeal approach. For example, the *Power Smart Program in B.C.*, while very effective from a marketing perspective, has only three program elements and therefore will likely have little overall effect[110]: Additionally:

- fluorescent lights (particularly compact units) are not implemented to the extent the program stipulates (lack of inspection/enforcement)[111], and there net energy reduction is less than 50% of gross, because of increased space heating requirements. The program also encourages the use of low-voltage halogen lights, which, while more efficient at task lighting (mainly due to internal reflectors) tend to result in little reduction in installed capacity (multiple lamps installed in a track are not individually switchable),
- low-flow faucets are either in common use or mandated already, in the majority of the target houses
- The only significant measure in the program is the use of low emissivity windows (which should have been in the MNECH - see discussion below)

Some examples of such programs that are in place that have been successful at improving energy efficiency include:

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[110] ***Power Smart New Home Pilot Program Evaluation***, by Allison & Associates/SAR engineering ltd. for B.C. Hydro, March 1995

[111] Also, the reduced internal gains due to the more efficient lighting will result in increased GHG in the 84% of B.C. houses that use natural gas heating (reducing GHG is not a goal of the Power Smart program, however)

Single-detached/attached houses:

The R-2000 Program is widely recognised for its leading edge technology in low-rise housing. Initially, R-2000 houses were designed to use about 50% as much energy as conventional houses, however the energy efficiency of conventional houses has improved significantly[112]. A 1994 NRCan study[113] found that R-2000 houses averaged about 63% as much space heating energy[114] as *Model National Energy Code for Houses (MNECH)* (version 1) houses and about 56% as much space heating energy[115] as 1995 NBC houses. There are regional variations as well, with R-2000 houses significantly more efficient in areas of inexpensive energy (natural gas heated homes in B.C and Alberta, for example), but about equal to current practice/MNECH in cold climates with expensive energy (electrically heated homes in Manitoba, for example). The reason for these differences is that the R-2000 program uses a performance based code, while the MNECH is driven by an economics model.

Advanced House Program houses were designed to use about 50% as much energy as R-2000 houses, or about 25% as much energy as conventional houses.

Multi-Unit Residential Buildings:

The *Model National Energy Code for Buildings (MNECB)* applies to multi unit residential buildings over three stories or greater than 600 m2. In Ontario, high-rise buildings can be built to either the MNECB or ASHRAE 90.1.

The C2000 program is the commercial and high-rise residential equivalent of the R2000 program. Currently, to meet the C2000 standard buildings must use 45% less energy than a building design to meet the ASHRAE 90.1 standard.

No MURBs have shown actual performance that met the C2000 standard to date, though several are currently being monitored or are under construction[116], including:

- Green on the Grand in Kitchener, Ontario (being monitored),
- Shoal Point, Victoria (just started construction), and

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[112] Note that some care must be taken in comparing relative energy efficiency and GHG reduction. Although new houses are more energy efficient, they are also generally significantly larger (increasing floor area by 1.5%/year, amounts to a 16% increase in 10 years), so overall GHG reduction has not kept pace with energy efficiency improvements.

[113] ***Comparison of R2000 with NBC and MNECH Houses***, by Charles Zaloum and Tom Hamlin for Natural Resources Canada, October 1994

[114] average of five locations (not weighted by housing stock or fuel type); R2000 averaged 73% as much space heating energy as MNECH for electrically heated and 52% as much space heating energy as for natural gas heated.

[115] average of five locations (not weighted by housing stock); R2000 averaged 58% as much space heating energy as NBC for electrically heated and 53% as much space heating energy as for natural gas heated.

[116] communication from Duncan Hill, CMHC

- Governors Road Project, Dundas, Ontario (design stage)

An analysis of one of these projects, the Shoal Point project in Victoria, BC, shows the type of approach that can be taken with multiunit residential buildings to meet the C2000 standard, and the potential for energy reduction. The building is 3 stories with 140 units, and is designed to use an ocean source heat pump, among other measures, to reduce space heating and domestic hot water energy consumption.

Table 3.20 Example C2000 Multi Unit Residential Building

	ASHRAE 90.1 Energy use		Achievable Energy Use		
	kWh/m2/y	% of total	kWh/m2/y	% reduction	
Heating (gas)	70	41%	13	82%	(GSHP - COP=5)
DHW (gas)	29	17%	5	82%	(GSHP -COP=4.7)
Lights	15	9%	13	10%	(improved lights & controls)
Equip. (fans, elevators)	15	9%	9	40%	(high effic. motors, variable speed makeup air with CO2 sensors)
Aux. Electrical	20	11%	18	10%	(improved appliances)
External lights	5	3%	4	10%	(improved lights & controls)
Transformers	13	8%	13	0%	
Cooking (gas)	5	3%	5	0%	
Total	171		80	53%	

Note that most of the energy use reduction is due to the GSHP, with a COP of 5 (this may be optimistic).

3.4.3 Fuel Switching

From 1990 to 1996 there was a move away from oil and electricity to natural gas for space and water heating. Natural gas' share increased from 41% to 48% over that period[117], largely due to increased availability and lower price. This trend will likely continue - particularly when natural gas becomes available in the Maritimes.

Switching fuels has the potential to effect GHG emissions in the following ways:

- reduced GHG emissions due to increased efficiency of replacement units compared to old stock,
- reduced GHG emissions due to switching from oil (75.3 kg GHG per GJ) to natural gas (49.9 kg GHG per GJ)[118],
- reduced GHG emissions due to switching from oil to electric heating in a hydroelectric or nuclear dominated generation grid (if marginal capacity is not fossil fuel generated) or
- reduced GHG emissions due to switching from electric heating to natural gas in a combustion (oil, gas, coal) dominated electrical generation grid.
- increased GHG emissions due to switching from oil to electric heating in a combustion dominated electrical generation grid,
- increase GHG emissions due to switching from electric heating to natural gas in a hydroelectric dominated generation grid (if marginal capacity is not fossil fuel generated).

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[117] ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan

[118] ***Background Information on Greenhouse Gas Emissions from Canadian Housing*** by J. Gusdorf, NRCan Buildings Group, October, 1998

3.4.4 Alternative Energy Supply Systems

While improving the end use energy efficiency of the residential building stock is one method for reducing GHG emissions, another method with a much greater potential is to reduce the resulting GHG emissions from the energy supplied to the building. This can be accomplished by improving the efficiency of the energy supply or by supplementing energy needs with energy supply systems that are lower (or zero) in GHG emissions. For example, the generation of electricity from natural gas fired electrical generation is typically in the order of 33%. However, natural gas fired co-generation systems that generate both electricity and heat energy have combined efficiencies in the order of 80 to 90%, significantly reducing the GHG emissions associated with each unit of energy delivered to the building. Renewable energy supply systems can deliver energy to the building with zero GHG emissions. To accomplish the same level of GHG reduction through increased energy efficiency of building envelope and appliances would be a difficult task.

This section looks at opportunities for alternative energy supply systems that can be installed in individual buildings or houses or for small collections of buildings. Energy systems at the community level are not included because they are being looked by the Municipalities Table.

3.4.4.1 Renewable Energy Systems

Renewable energy is any sustainable energy source that comes from the natural environment. The most common forms of renewable energy are solar, wind, water or hydro, biomass and geothermal energy. Renewable energy sources are maintained or replaced by nature after use. Although renewables cannot yet replace all existing energy sources, they can supplement power generated by utilities and increase the diversity of our energy supply.

Economically, the advances that have been made in renewable energy technologies in the last two decades, including higher efficiencies, improved quality and increased reliability, have made applications of renewable energy more attractive. However, many residential scale renewable energy technologies are still not competitive when compared to bulk power generation, except for remote and off-grid applications.

Active Solar Hot Water Heaters

Off the shelf solar hot water heating systems are readily available for pool heating, DHW heating, and space heating applications.

> ***Active Solar Pool Heaters*** - The most cost effective solar hot water heating systems on the market are solar pool heaters. Simple, inexpensive, unglazed black plastic solar collector systems are readily available that can provide all of the heating needs for residential single and multi family outdoor swimming pools from spring until fall, eliminating both fossil fuel consumption and capital costs of conventional heating equipment. The systems are simple to install, and generally have 3 to 6 year simple payback periods. NRCan has estimated the technical

potential for CO2 abatement of cost competitive residential active solar pool heaters at 0.65 Megatonnes per year by the year 2010[119].

Active Solar Domestic Hot Water (DHW) Heaters - Various active solar domestic hot water heating systems are available that vary in complexity, efficiency, and cost. Depending on how the system is designed and used, they can provide 50 to 75 per cent of a family's hot water needs[120]. With water heating accounting for about 20 per cent of home energy use, a solar DHW system is an attractive method of reducing a home's fossil fuel consumption.

The most cost effective systems available are batch collectors that can be installed inline between the building's water supply and existing DHW heater, eliminating the need for any new pumps or tanks. The main drawback with these systems is that they can not be used when the temperature is below freezing and require draining for freeze protection. These types of systems have payback periods of approximately 8 years and up.

The most common residential active solar hot water heaters typically use glazed collectors mounted on a roof and connected to a storage tank. Fluid is pumped to the collectors where it is warmed by the sun, then returned to a heat exchanger where it heats the water in a storage tank. They are more efficient than batch water heaters and can be used year round. Modern solar water heaters are now relatively easy to maintain and can pay for themselves with energy savings over their lifetime. An efficient solar hot water heater of this type can collect approximately 2GJ/m2 of collector area per year of energy in most parts of southern Canada. A typical system has about 6 square meters of panel area, collecting approximately 12 GJ of energy per year, and costs about $3000. As a result, the simple payback period on these systems is about ten years if the system is reducing electrically heated hot water energy consumption, and longer for natural gas.

A new system which has been developed by NRCan will cost about $1700 installed and is expected to be on the market in 2001. The price of these systems has dropped about 75% since the early 1980's. In 1981 a typical system cost about $5300 (in 1987 dollars), compared to $1300 (in 1987 dollars) for the new system developed by NRCan.

Other systems available include thermo-siphon systems that eliminate the need for pumps, which are common in Southern Europe. Evacuated tube collectors are also available that are more efficient but also more expensive with longer payback periods.

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[119] CANMET, Active Solar Heating in Canada to the Year 2010, 1993.
[120] Solar Energy Society of Canada Active Solar Fact Sheet

NRCan has estimated the technical potential for CO2 abatement with cost competitive residential domestic hot water heaters at 4.27 Megatonnes per year by the year 2010[121].

It is expected that in the future utilities & energy companies will lease solar domestic hot water systems to customers. Currently, larger buyer groups for purchasing solar domestic hot water systems in bulk are being formed under the International Energy Agency's Solar heating and Cooling Programme.

Active Solar Space Heating

Typical active solar space heating designs are similar to active solar domestic hot water systems, using glazed collectors to heat a fluid held in large storage tanks. Heat from the storage tanks can be transferred to a radiant floor heating system, a baseboard radiant heating system or through a fan coil unit to a forced air system. The latter two methods require relatively high temperature fluid which requires very efficient (expensive) solar collectors. These are all relatively expensive methods of providing winter heating in Canada - conservation and passive solar provide better economic returns.

On a larger scale these systems can be used to create a seasonal storage of heat in large reservoirs, which could be used to supply heat to residences through a district-heating network.

Active Solar Ventilation Air Heating

A technique available for reducing the energy required to heat ventilation air is to use solar energy to directly preheat the air drawn into the building. Commercially available systems of this type typically use a darkly coloured, perforated aluminium sheet mounted on a south-facing wall. As the sun heats the sheet, a fan draws solar heated air through the perforations, warming the air. This preheating can significantly reduce energy use by conventional heaters to bring fresh air up to room temperature. NRCan and Conserval Engineering are scheduled to begin development of a new residential "Solarwall" that incorporates heat recovery ventilation. Energy savings are expected to be about 14 GJ/year/household, and the product is expected to be on the market in 2001. NRCan has estimated the technical potential for CO2 abatement with cost competitive residential ventilation/HRV solar preheat systems at 1.65 Megatonnes per year by the year 2010[122].

Photovoltaics

Since 1980 the price of PV modules has dropped by approximately 80 percent, and there is currently a world-wide boom in PV sales, much of which is driven by government support for solar home systems in a number of countries. In Canada, however, electricity from solar power systems still costs about 4 to 5 times the price of grid supplied electricity, making them only cost effective for off grid customers.

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[121] CANMET, Active Solar Heating in Canada to the Year 2010, 1993.

[122] Ibid.

A number of technological advances and utility changes are making PV systems more attractive. One change is the integration of solar cells into roofing shingles, tiles, and window glass, eliminating the initial cost of these building materials. Another change is the use of net metering, where the systems are connected to the grid and utilities purchase the excess electricity generated, ideally at the same price that they sell electricity for. Battery storage systems and controls can be eliminated, substantially reducing the system costs.

A number of countries are providing direct support for home PC systems. Japan is leading the way with generous subsidies for rooftop systems and requires electric utilities to purchase the electricity from customers at the same price that they sell it for. Europe and the U.S. have both launched "Million Roofs Initiatives" designed to dramatically boost the size of the market, using tax credits, policy changes, and partnerships with utilities and local governments (these programs also include solar domestic hot water). One utility in California is paying for and installing roof mounted systems on customers' houses. By 2002, they are expect the fully installed costs of their roof mounted systems to have dropped to $3000 US per kilowatt, providing power for roughly 9 cents per kWhr[123].

Although a few grid-connected projects have been demonstrated in Canada, no electric utilities are set up to purchase back generated electricity at a reasonable price. If every single family house in Canada provided 1 kWh per day of solar power, the GHG emission reductions would average out to approximately 22 kg per house per year or 123,000 tonnes total. [21]

Ground Source Heat Pumps

Ground source heat pump (GSHP) systems fall into the category of renewable energy since they utilise the heat from renewable solar energy stored in the ground. Ground source heat pumps are referred to under many names, including geothermal, geo-exchange, earth-coupled, water-coupled, groundwater, ground-coupled, closed-loop, coiled or slinky, open, and water-source heat pump systems.

These highly energy efficient systems are being installed in considerable numbers primarily in the USA, Canada, Scandinavia (mainly Sweden), Switzerland, Austria, and Germany. A number of other countries are beginning to show an interest in installing this space heating/cooling technology. Currently the highest level of activity is taking place in the USA where the Geothermal Heat Pump Consortium is co-ordinating a campaign to increase the number of installed units from 40000 units per annum tenfold to 400000 units per annum by the year 2000..

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[123] World Watch, September 1998.

GSHP systems provide space heating and/or cooling and hot water for many types of buildings in any climatic situation in most geological settings. They are one of the most efficient means available in Canada to provide space heating and cooling for homes. Unlike air source heat pumps they remain efficient in cold climates.

GSHP's transfer the heat in earth's surface (or in a body of water) into a building in winter, and transfer the heat in the building to the ground or water in the summer, using the same principle as a refrigerator. The heat obtained from the ground is much greater than the electrical energy that is required to drive the various components of the system. The efficiency of a unit is the ratio of heat energy provided versus the electrical energy consumed to obtain that heat, and it is called its Coefficient of Performance (COP). GSHP units sold in Canada must exceed a COP of 3.0, resulting in 1/3 or less electricity consumed than with the use of electric resistance heating.

Systems can be designed to use water from a lake or well on a once through basis (open loop systems) or use closed loops installed in a lake bottom, horizontal trenches, or vertical bore holes through which water or antifreeze solution is circulated from an indoor heat pump. A de-superheater on the heat pump can optionally provide water heating at much higher efficiencies than conventional hot water heating technology.

Ground-source heat pumps are more expensive to install than gas, oil or electric heating units, but can be competitive with combination heating/cooling systems. For this reason, heat pumps are most attractive for applications requiring both heating and cooling.

However, with a COP of 3.0, the cost for heating is only one-third of the cost to operate an electric resistance heating system, such as electric baseboard heaters or an electric furnace. With a COP of 4.0, the savings can be as much as three-quarters off the price of electric heating and cooling.

An average house of 2,000 square feet of living space in central Canada would require a four-ton heat pump unit which would cost from $4,000 to $6,000 for the heat pump component; and a de-superheater would add $1,000. To install the loop, the cost would be:

$3,000 to $5,000 for an open-loop water system
$4,000 to $6,000 for a closed-loop lake system
$6,000 to $9,000 for a closed-loop horizontal
$8,000 to $12,000 for a vertical loop

The simple payback period for these systems ranges from approximately 5 to 12 years[124].

Wind Turbines

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[124] Canadian Earth Energy Web Site

Wind power is a very fast growing renewable energy source, particularly at the utility scale level. In the last decade costs for wind-generated electricity have dropped from 30¢ per kilowatt-hour to 7¢ per kilowatt-hour. Canada has about 22 megawatts of wind generation plant installed producing about 64,000,000 kilowatt-hours of electricity per year - enough to supply about 7,900 typical Canadian homes. This capacity results in about 1.5 installed watts per capita average for the country. This can be compared with Denmark, for example, which has 122 watts per capita of installed wind generation capacity.

Wind-diesel projects in remote northern Canadian locations have demonstrated that wind energy can reduce the high costs associated with transporting diesel fuel to these remote sites. While wind generated electricity is not practical in most cases on the individual building level, it has huge potential at the utility level and could possibly be used on a building cluster or community level.

Passive Solar Heating

Passive solar heating represents an important strategy for displacing traditional energy sources in buildings. Passive solar techniques make use of solar energy by means of building designs that carefully balance their energy requirements with the building's site and window orientation.

All passive techniques use building elements such as walls, windows, floors and roofs, in addition to exterior building elements and landscaping, to control heat generated by solar radiation. Solar heating designs collect thermal energy from direct sunlight, store the collected energy in the thermal mass of the building elements or other storage, and release it back into the interior of the building as required. The benefits of using passive solar techniques include simplicity, price and the design elegance of fulfilling one's needs with materials at hand.

Care must be taken in designing passive solar dwellings in order to avoid overheating. This issue was addressed in a recent study[125], with the results and many other design tips incorporated into a CMHC design handbook and CD-ROM ("Tap the Sun").

High efficiency windows, together with R-2000 levels of insulation and air-tight construction allow passive solar heating to cover a large proportion of heating needs in many locations in Canada. With the heat contained, often a simple ceiling fan or a forced air furnace fan is all that is required for heat distribution. Using building envelope upgrades alone, passive solar designs can achieve a solar contribution of up to 25 per cent of a building's heating load. This represents an increment of about 15% over the solar fraction of a normal, well insulated house built without attention to passive design[126].

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[125] ***Overheating as a Factor in House Design***, by SAR engineering ltd. for CMHC, May, 1997
[126] CANMET, Passive Solar Potential in Canada: 1990 - 2010, 1990.

A study prepared for NRCan in 1990 predicted the following technical and market potential for passive solar technologies by the year 2010, assuming uptake rates starting in 1990. Both single and multi unit residential buildings are included in these estimates[127].

	Ultimate Passive Solar Potential (PJ/Year)	**Technically Feasible Potential (PJ/Year)**	**Reasonably Achievable Market Potential (PJ/Year)**
Residential Retrofit (Pre 1989)	296	136	36
New Residential (1989-2010)	151	53	25
Total Residential		447	189

Another solar concept is daylighting design, which optimises the use of natural daylight. Use of light shelves and clerestory windows are two methods by which sunlight can be directed to the back of a space - providing a more uniform illumination.

Under cooling conditions, natural lighting has an advantage over other forms in that about 50% of the energy in sunlight is visible light, while the visible portion of artificial light is much lower (incandescent ~6%, fluorescent ~20% to 25%). The higher proportion of heat in artificial light adds to the cooling load. Full integration of natural and artificial lighting requires careful design and sophisticated lighting controls.

Passive Cooling

The term natural cooling, or passive cooling as it is often referred to, applies to various simple cooling techniques that enable the indoor temperature of buildings to be lowered through the use of natural energy sources. Usually the cold collecting and storage elements are an integral part of the building itself such as the building envelope or structure or the soil under the building. Natural cooling of a building requires the utilisation of natural heat sinks, such as ambient air, the upper atmosphere, water, or soil for removing heat from the building.

There are many different natural cooling techniques available to designers. Not all are strictly passive systems since some require the use of fans or pumps for transferring heat. But all of these systems use natural heat sinks and if fans or pumps are used they use much less energy than conventional air conditioning. These techniques or systems can be classified according to the following broad categories:

- Comfort Ventilation - improving comfort when the indoor temperature is too warm, by using natural ventilation to increase indoor air speeds
- Nocturnal Ventilative Cooling - utilising a high thermal mass building which is cooled at night by ventilating the building with cool night air.
- Radiant Cooling - using the roof of a building, a heat storage mass on the roof, or lightweight radiators to cool the building at night under the principal that any surface will transfer heat to the sky at night through radiation at night.

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[127] ibid

- Evaporative Cooling - adding water to the air (such as with cooling towers) to reduce its temperature in a process called adiabatic cooling and then sending the cooled air into the building, or cooling the roof of the building with a pond that evaporates its water to the outside air.
- Soil Cooling - constructing buildings with earth around and above whereby cooling occurs through passive conductive cooling through the walls of the building. Another approach is to build an insulated building above ground and circulate ventilation air or water through pipes in the soil where it is cooled.

For all passive cooling designs solar and internal heat gains should be minimised through shading and proper daylighting design, which optimises the use of natural daylight and contributes greatly to energy efficiency by reducing the energy required for lighting and reducing related cooling loads.

The need for air-conditioning in homes in Canada can be greatly reduced or even eliminated by using passive cooling designs. Different passive cooling techniques are be more appropriate for specific regions depending on air temperature, humidity, availability of wind, night-time air temperatures, cloud cover, soil temperatures etc.

3.4.4.2 Fuel Cells

Fuels cells capable of providing all the electric needs of the average home are presently in the development stage, and may be on the verge of breakthrough as an economical alternative to traditional energy sources. Fuel cells convert the energy of fuel (hydrogen, natural gas, methanol, gasoline, etc) into electricity through an electrochemical process, without producing combustion emissions such as particulates, carbon monoxide, or nitrogen or sulphur oxides.

Fuel cells running on hydrogen derived from renewable sources produce no CO2 emissions. Running on other fuels they generate less CO2 than fossil fuel generated electricity due to improved efficiency. (40 to 85%)

GE Power Systems and Plug Power in the United States are developing residential based fuel cell systems to sell, install and service. They demonstrated a hydrogen powered 7 kW residential power system in a test home this summer and are developing units that run on natural gas, propane or methane. The systems are expected to achieve 40% electrical efficiency without heat recovery and 70-85% making use of excess heat for domestic hot water or heating. They are planning the sale of test units next year followed by commercial units in the year 2000, at projected unit prices of US $3000-5000. At this price they could generate electricity at 7-10 cents US per kW hour.[128] According to the company, home-brewed electricity could cost 20% less than that from the grid. Further, off-grid power generation would reduce the need for long distance power lines, thus make existing power plants more efficient. The line loss from power transmission to a home is about 7-8%.

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[128] Matthew L. Wald, New York Times, 17 Jun 98, p A27

3.4.4.3 Co-generation

Co-generation is a highly efficient means of generating heat and electric power at the same time from the same energy source. Displacing fossil fuel combustion with heat that would normally be wasted in the process of power generation, it reaches efficiencies that can triple conventional power generation.

Micro co-generation systems appropriate to the individual building level have excellent future prospects. In regions supplied by fossil fuel generated electricity, on site co-generation systems can displace electricity generated at 36% efficiency with combined heat and power generated at 80 to 90%, achieving large GHG emission reductions that would require great effort to achieve on the end use energy efficiency side.

Co-gen systems can provide electricity plus heat for space and water heating in winter, and the waste heat can be used through absorption cooling to provide cooling in the summer. They can also be grid connected to sell electricity back to the grid when extra capacity is available.

Whereas 15kW was the lower limit of cogen systems a short while ago, recent advances in technology have made it possible to design smaller mini co-gen systems. An 800 Watt system using a Stirling engine is currently under test in the Netherlands. Three companies in the US are developing small gas fired co-generation systems, one in the 50 kW range, that will have large advantages over small diesel cogen units that are presently available. These systems are expected to be much lower cost, vibration free, and require less maintenance. Another company in the US has designed a small absorption chiller of the residential size capacity. Presently, cogen is only competitive in off grid applications and locations with high electricity prices.

Another co-generation technology that has great potential is the use of free-piston Stirling engine-alternators that are particularly suited for use as small scale natural gas fired micro-cogen and cooling devices. Stirling based cogen systems offer significant potential advantages over internal combustion engines in efficiency, life, noise and emissions. The ability of Stirling machines to maintain higher efficiencies at lower power levels than internal combustion engines significantly expands the potential market for micro-cogen. Machines of this design are being considered for production in the near future as gas-fired units for combined heat and power in sufficiently large quantities to assure competitive prices for the final unit[129].

Co-generation equipment can also be fired by fuels other than natural gas. There are installations in operation that use wood, agricultural waste, peat moss, and a wide variety of other fuels, depending on local availability.

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[129] Neill W. Lane and William T. Beale, Stirling Engines for Gas Fired Micro Cogen and Cooling, Presented at Strategic Gas Forum, Detroit, Michigan, June 19-20, 1996

3.4.5 Shared Energy Generation Systems

There is frequently an optimal scale for certain technologies in terms of costs, energy efficiency and GHG emissions reduction. Many technologies that have great potential for reducing GHG emissions are not presently cost effective at the building scale but would be more viable at a larger scale. Often technologies are more appropriate if they serve a small number of buildings at the "cluster" level, or the block, subdivision, neighbourhood, municipal, or "distributed" utility level.

While the Municipalities Table is responsible for looking at the potential of energy systems at the community level, and the Electricity Table will be looking at distributed utility scale electrical supply options, a key opportunity that is missed is the possibility of cluster level systems incorporated into new residential developments.

Some technologies are not cost effectively available at a size as small as the individual building level, or their efficiency is greater at a larger scale. For example, reliable and efficient micro-cogen systems are being developed in the 25Kw size range that is too large to serve an individual house but could be used to serve a cluster of approximately 10 houses. The cost of the piping systems increases as the pipe size increases. And absorption chillers that can use the waste heat for cooling are not available in very small sizes. The most economically efficient scale of the system depends on an optimisation process, the results of which will change in the future as the most cost effective size of commercially available equipment changes.

There is a similar economically optimum shared size for other improved efficiency energy supply systems such as ground source heat pumps, and high efficiency boilers, and for certain renewable energy supply systems such as wind generation.

Many types of alternative energy supply systems at the building or cluster level can also contribute to more desirable distributed utility level energy supply systems. Distributed energy supply systems can have a number of advantages. Power is generated close to the power consumer, reducing transmission losses, stray current, and the need for distribution equipment significantly. Co-generation plants tend to be built smaller, and owned and operated by smaller and more localised companies. As a general rule, they are also built closer to populated areas, which causes them to be held to higher environmental standards. And distributed energy supply systems have lower stranded costs and can adapt as more efficient technologies are developed.

3.5 TECHNICAL POTENTIAL SUMMARY

The opportunities for reduction in energy use and GHG emissions have been investigated in this chapter on a component basis and for the whole building. The effects of changes in most components are not additive because they must also take into account their effect on other parts of the 'house as a system'.

Component Scenarios

Table 3.22 provides a summary of the technical potential for a selection of the GHG reduction opportunities in the residential sector that were discussed throughout this chapter.

Table 3.22 Technical Potential for Reducing Residential GHG Emissions

	GHG Emissions			Reduction		
	1990	1996	2010	1990 to 2010		
	(Mt CO_2 equivalent)			(Mt CO2 equivalent)		
				Gross	Net	Net
Space Conditioning						
Space Heating	42.4	43.7	~30.4		12.0	28%
with passive solar[130]			*~24.0*		18.4	
Space Cooling	*~0.3*	0.3	*~0.3*		0.0	0%
Ventilation	0.0	0.0	1.0		-1.0	
Water Heating	13.7	16.1	13.4		0.3	2%
with solar or heat rec.overy[131]			or 7.2		or 6.5	23%
Lighting	*~3.0*	3.2	1.2	1.8	0.9	27%
Appliances	10.4	9.7	9.4	1.0	0.5	5%
TOTAL RANGE	70.6	72.7	55.7 to 43.1		12.7 to 25.3	18% to 36%

The assumptions used in each case have been noted in the previously discussion for each measure respectively. Note that the GHG emissions include emissions associated with energy consumed directly on site, as well as those from electrical generation, taking into the current energy fuel mix. Net reductions shown in the table are net GHG reductions after allowing for increased space heating requirements resulting from decreased electrical consumption inside the dwellings. The technical potential figures shown in Table 3.1 take into account an increase in the total housing stock of 16% between 1996 and 2010. They also assume virtually 100% implementation of each of the technologies by 2010, except for in the case of appliances which are based on energy efficiency and penetration rates for appliances in Canadian houses provided by NRCan.

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[130] Assuming the 189 PJ total technical potential in Table 3.21 was based on the current housing stock (as conservation levels increase, the heating demand decreases and the passive solar technical potential will also decrease somewhat.

[131] Assuming that by 2010, 40% of all dwellings have either a solar DHW system, contributing 50% of DHW demand, or grey water heat recovery recapturing 40% of heating demand.

Whole Building Scenarios

Two whole building scenarios were also investigated in this chapter with the results presented below. These scenarios do not provide definitive answers on the best options for reducing GHG emissions, but are used to provide a sense of what is possible given the technical potential of the various technologies and all of the component interactions discussed in section 3.4.2. The REES model was used as the primary tool for these evaluations. REES has several advantages for this type of analysis, but it also has some limitations that had to be worked around with manual calculations[132]. The results of analyses of one scenario for single family dwellings, attached dwellings, and multi-family dwellings is presented.

Single Detached:

Figure 3.2 and Table 3.23 show the results of one scenario of GHG reduction for single detached existing and new housing, that performs three levels of analysis:

- GHG emissions from direct energy (at the house),
- GHG emissions from direct energy and from electrical generation, and
- GHG emissions from direct energy, from electrical generation, and embodied emissions from construction of new houses and retrofits

Table 3.22 Single-Detached Residential Greenhouse Gas Projections

	Direct Emissions		Direct and Electrical Emissions		Direct, Electrical and Embodied Energy Emissions		
Year	CO_2 Equiv. (%)	Energy Retrofit Costs ($ 10^6/yr)	CO_2 Equiv. (%)	Energy Retrofit Costs ($ 10^6/yr)	CO_2 Equiv. (%)	Energy Retrofit Costs ($ 10^6/yr)	Kyoto Goal (%)
1990	100%	0	100%	0	100%	0	**100%**
1995	105%	0	106%	0	108%	0	
2000	99%	1,973	102%	1,973	105%	1,973	
2005	94%	1,972	98%	1,972	101%	1,972	
2010	**88%**	**1,971**	**94%**	**1,971**	**97%**	**1,971**	**94%**
2015	82%	1,971	90%	1,971	93%	1,971	(2008-2012)
2020	75%	1,970	86%	1,970	89%	1,970	
2025	69%	1,970	81%	1,970	84%	1,970	
2030	62%	1,969	76%	1,969	79%	1,969	

The energy-related cost of the retrofit measures is approximately $2 billion per year, which represents about 10% - 15% of the current annual total cost of retrofit/repair for the entire residential sector).

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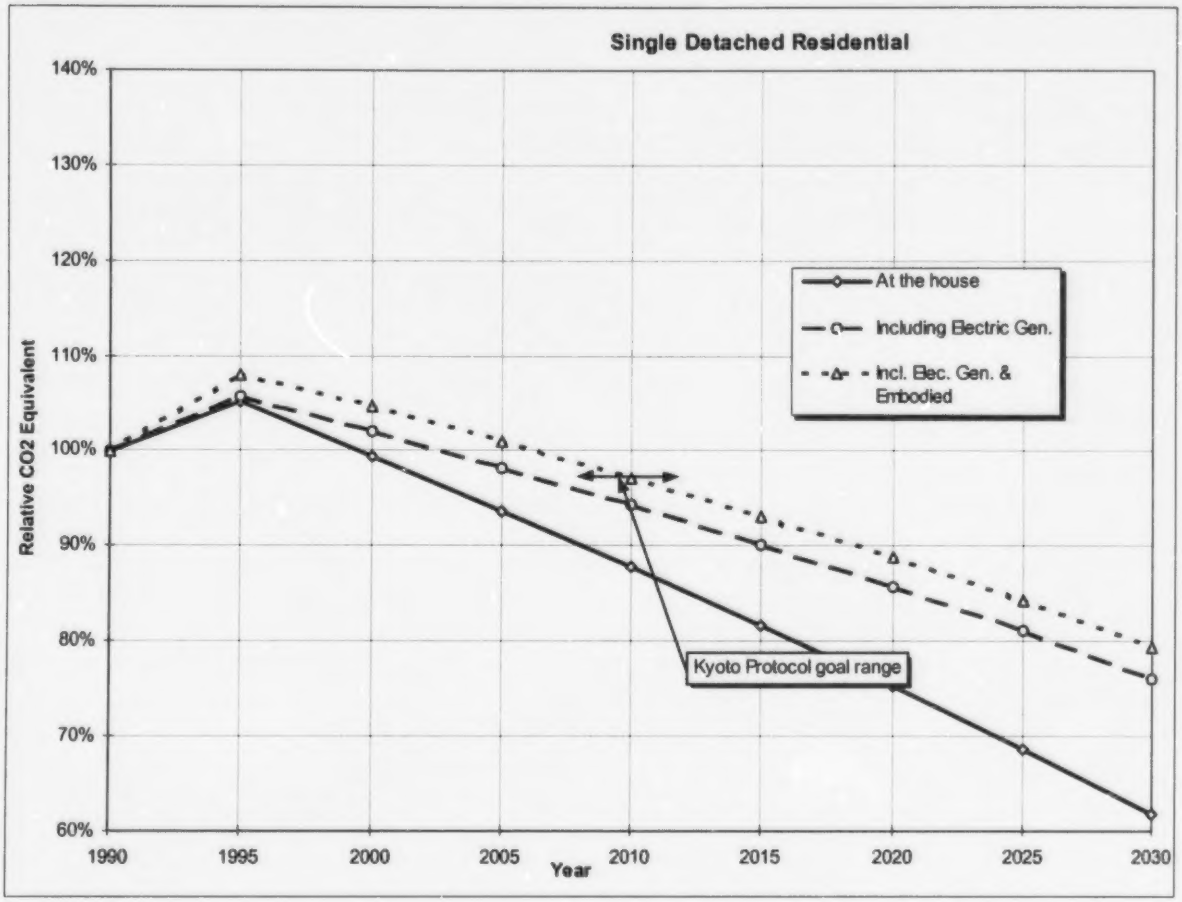
[132] REES (Residential Energy and Economic Simulator) was developed for the ***Residential Retrofit Potential in Canada***, by SAR engineering ltd. for CMHC. Because it processes 965 actual houses from the expanded STAR database, it is able to retrofit only that portion of the housing stock that result in a good return on the investment. However, to obtain results for the entire housing stock, the REES results were combined with spreadsheet calculated estimates for attached housing and apartments.

Figure 3.2 Scenario of Greenhouse Gas Projections for Canada's Single Detached Residential Housing Stock



Some of the assumptions for this scenario include:

- 41% of all 1990 houses retrofitted by 2010 (3.4% per year from 1998),
- Existing houses are retrofitted to a level almost comparable to current R-2000 houses -
  - Insulation levels 30% higher than MNECH
  - Glazing ER 6 points higher than MNECH
  - Improved air-tightness (based on type of retrofit), but would not meet R-2000 requirements,
  - Ventilation to NBC requirements
- Switching from oil to natural gas, where available, and from electric to natural gas in provinces where combustion generated electricity predominates.

- New houses are gradual improved in energy efficiency until almost comparable to current R-2000 houses by 2010 (using about 63% of the energy of 1990 houses - due to a combination of improvements in energy efficiency and slightly reduced size).

Not included in the scenario are the effects of:

- using GSHP instead of electric resistance heating (mostly effects new houses),
- using improved passive solar design (effect could range from minimal to significant - depending on type of program),
- using solar DHW (~2% further reduction in GHG emissions),
- adding heated floor space during retrofits (increasing GHG emissions)

Attached Housing:

Relative GHG reductions for attached low-rise housing (duplex, row) should be similar to that for single detached as the type of construction and heating systems are similar.

Apartments:

Apartments have a smaller relative potential for retrofits (particularly high-rise), but could see improvements in glazings, air-tightness, ventilation heat recovery and central heating systems (the latter only constitute about 50% of apartments, however). Significant improvements could be made to the energy efficiency of new apartments, with more air-tight and better insulated envelopes, improved glazings, heat recovery ventilation[133], and greatly improved heating systems (condensing gas/oil boilers, GSHP electric). Under these circumstances, greater care would have to be taken to prevent overheating due to solar and/or internal gains. Solar DHW would be particularly applicable for apartments with central DHW systems (about 65% currently).

Table 3.24 provides an approximate breakdown of projected energy use by dwelling type.

Table 3.24 Residential Energy Use: Current and Projected

	Current			Projections			
	1996 Number of Dwellings[134]	Energy use per dwelling (GJ/y)	1996 Energy Use (PJ/y)	2010 Number of Dwellings	Energy use per dwelling (GJ/y)	2010 Energy Use (PJ/y)	Relative Energy Use 2010 vs 1996
Single Detached	6,329,638	151	958	7,386,500	113	835	87%
Attached, Row	1,201,830	109	131	1,260,600	83	105	80%
Apartment	3,697,058	82	304	3,857,100	~62	240	79%
Mobile	217,474	114	25	221,700	~101	~22	90%
Total Dwellings	11,446,000		**1417**	13,277,360		**1203**	85%

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[133] With better distribution of ventilation for improved comfort (and reduced occurrences of occupants opening windows for fresh air during periods when heating is required)

[134] Personal communication with Cristobal Miller

With a toal residential energy use of 1294 PJ in 1990, the measures described in this scenario would result in an energy use of 1203 PJ, for a reduction of 7% and a reduction in GHG of approximately 5% to 6%, relative to 1990 (including emissions due to electrical generation).

3.6 INFORMATION GAPS AND AREAS FOR FURTHER RESEARCH

1. Further work must be performed to identify the economic potential of each opportunity, creating cost benefit curves for each, and ranking.
2. There is insufficient information about the stock, equipment, and performance levels of Multi-Unit Residential Buildings to devise accurate models or programs for this type of dwelling. Additional surveys of mid-rise and high-rise buildings across Canada and the creation of a database of information of should be carried out.
3. Research and data is also lacking on MURB new construction and retrofit potential, particularly for mid and high rise apartments.
4. Because of all the thermal interactions of the various components, there is a need for an integrated residential sector thermal and GHG simulation model, such as REES, to ensure that economic models have the correct inputs. Simulations based on archetypes, using models such as HOT2000 include the effect of outliers (extremes) that can have a significant influence on the results. A model that uses a database of actual dwellings, such as REES, can allow for the variability of houses within a category (age group, region, etc.). This allows for the inclusion or exclusion of dwellings with extreme characteristics, depending on the analysis.
5. Further work must be carried out to define the optimal level for providing services (such as shared energy systems) and to develop means to encourage that development incorporate optimal scale (eg. district energy has obvious benefits but there are many institutional barriers to its use)
6. Examine a complete range of proven, energy-efficient technologies and identify those where a change to high volume production (due to regulations or other changes) might create significant reductions in market prices and increased achievability.
7. The potential impact of opportunities for biomass and wood stoves should be investigated.
8. More research is required to identify the impact of GHG reduction on housing affordability.

END NOTES:

1. ***Home Energy Retrofit in Canada, Overview & Opportunities***, March 1994, for Natural Resources Canada, CMHC, Ministry of Natural Resources of Quebec, Ontario Ministry of Environment and Energy, and Hydro Quebec. Includes recommendations emerging from the Retrofit Options Workshop
2. ***Residential Retrofit Potential in Canada***, Feb. 96, by Ken Cooper, SAR engineering ltd. for CMHC
3. ***Modification of the REES Software***, September 1998, by Ken Cooper, SAR engineering ltd., for NRCan
4. ***Energy Efficiency Trends in Canada, 1990 to 1996***, June 1998, by/for NRCan
5. ***Canada's Energy Outlook 1996-2020***, 1997, by/for Natural Resources Canada
6. ***An Assessment of the Greenhouse Gas Emission Projections in Natural Resources Canada's Energy Outlook, 1996-2000*** by Michael Margolick, 9 Feb 98, for Auditor-General, Commissioner of Environment and Sustainable Development - critique of Energy Outlook report.
7. ***1993 Survey of Household Energy Use, National Results*** (also ***Provincial Results*** and *Technical Appendix*), November 1994, for Natural Resources Canada
8. ***Size and Importance of Small Electrical End Uses in Households*** by Broderick, of D&R International, and Zogg, Alberino of A.D. Little Inc.
9. ***Field Investigations of Indoor Environment and Energy Usage in Mid-Rise Residential Buildings***, August 1997 by Scanada Consultants Ltd./SAR engineering ltd. for CMHC.
10. ***Comparison of R2000 with NBC and MNECH Houses***, October 1994, by Charles Zaloum and Tom Hamlin for Natural Resources Canada
11. ***Power Smart New Home Pilot Program Evaluation***, March 1995, by Allison & Associates/SAR engineering ltd. for B.C. Hydro
12. ***R-2000 Monitoring Program Data Processing Results***, March 1995, by Ken Cooper, SAR engineering ltd. for Natural Resources Canada
13. ***Advanced House Monitoring Comparative Results***, August 1998, by Ken Cooper, SAR engineering ltd. for Natural Resources Canada
14. ***Preliminary Analysis of the Industrial, Commercial and Residential Sectors***, September 1997, by A. Bailie et al of The Energy Research Group, SFU for BC Greenhouse Gas Forum Working Group Three
15. ***Residential HVAC Controller***, in progress, by L. Bertsch of Horizon Technologies Inc. for NRCan
16. ***Residential HVAC Controller Sensitivity Analysis,*** in progress, by K. Cooper of SAR engineering ltd. for NRCan
17. ***Background Information on Greenhouse Gas Emissions from Canadian Housing*** by J. Gusdorf, NRCan Buildings Group, October, 1998
18. ***Energy Efficiency and Penetration Rates of Appliances in Canadian Houses*** by J. Gusdorf, NRCan Buildings Group, August, 1998
19. Cold Climate Design House (R-2000 house in Edmonton, AB) is an example of an energy efficient attached house with a livable basement. Total floor area of 171 m^2 is less than Canadian average of 186.5 m^2. Monitored energy use averaged 21.9 GJ per person per year. [12].
20. ***Advanced House Technologies Assessment***, by Scanada Consultants Ltd. for NRCan, February 1996
21. REES simulations (unpub.) by Ken Cooper, SAR engineering ltd., for NRCan, October 1998

4.0 WHAT HAVE WE LEARNED FROM PAST INITIATIVES ABOUT HOW TO DESIGN POLICIES FOR INFLUENCING THE RESIDENTIAL SECTOR?

This chapter presents a brief and selective review of energy efficiency initiatives directed at the residential sector and addresses two primary objectives:

1. To understand the scope of market interventions employed by governments and other organisations to foster investments in energy efficiency; and

2. To identify some of the key lessons learned from the rich and diverse experience of such interventions.

Specifically, this profile reviews the following:

◊ A brief discussion of the range and types of past and present initiatives directed towards fostering residential sector energy efficiency measures.

◊ A Review of **Past Experience**: It is beyond the scope of this assignment to document and assess all energy efficiency initiatives launched in the past 15 years or so. Rather, the focus is to identify trends set and lessons learned.

◊ A Review of **New Activity**: This will include a discussion of current initiatives and the market forces which will influence residential energy efficiency initiatives in the near to mid-term. An effort will also be made to understand how the new activities relate to past experience.

4.1 A TYPOLOGY OF RESIDENTIAL POLICY AND PROGRAM EXPERIENCE

The purpose of this section is to present an overview of the various ways in which public and private sector organisations have, and can potentially continue to, intervene in the residential market to attain energy efficiency goals. For the purposes of this review, policies and programs are defined as *any action initiated by government, institutions, and the private sector to address barriers to achieving economic energy efficiency improvements or fuel switching.*

- It is generally accepted that governments and utilities have played significant roles in fostering the market penetration of energy efficiency in the residential and other sectors of the economy. These organisations have "intervened" in the market to promote a wide range of programs and initiatives. It is also commonly held that many of these market interventions have been designed to address one or more market barrier.

- Market barriers to energy efficiency refer to a broad set of market features that appear to explain why actual levels of investment in energy efficiency have consistently fallen below optimal levels as viewed either from private or social perspectives.[135] Evidence of the existence of market failures or barriers is generally viewed as a necessary condition for market interventions to improve social welfare.

4.1.1 Types of Market Interventions

Table 4.1 (overleaf) summarises the types and range of market interventions that have been employed in various jurisdictions, with a particular focus on the North American experience. The experience embodied in these initiatives suggests that market interventions can be employed to:

i. *improve the operation of the market*: Types of activities that fall into this category include, for example, licensing and accreditation of service professionals.
ii. *require individuals and firms to behave in specified ways*: Types of activities that fall into this category include development and enforcement of standards and regulations.
iii. *influence the decisions of individuals and firms*: Types of activities that fall into this category include information dissemination, and the provision of financial incentives.
iv. *Provide goods and services directly*: Types of activities that fall into this category include energy audit services; energy performance contracting; the direct installation of specific appliances and equipment; and the buy-back of inefficient appliances and equipment.

There are two strategic points at which interventions can influence energy efficiency investments in the residential marketplace:

i. *At the time of equipment and dwelling turnover*: This is generally the easiest time for an energy efficiency initiative. The most common application is when consumers seek to replace equipment that has reached the end of its useful life, or when purchasing a new dwelling.
ii. Prior to the stock turn-over (either the dwelling or equipment): Examples include energy retrofits being piggy-backed to renovations, and the purchase of a new appliance before the end of its useful life. This represents the more difficult timing for energy efficiency measures.

The forms of market intervention in Table 4.1 also run the full spectrum from mandatory action supported by legislated regulations, to largely information-based initiatives designed to complement existing private sector driven activities.

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[135] Marbek Resource Consultants, Industrial and Commercial Energy Management Potential: Next Generation Options and Strategy: A Discussion paper. Prepared for Environment Canada, 1997.

TABLE 4.1
TYPES OF PREVIOUS POLICIES AND PROGRAMS

1. Dissemination of Information

1.1 Broad Consumer Awareness	This refers to advertising through various media (print, radio, television) to inform consumers of the benefits, both financial and environmental, of energy efficiency investments.
1.2 Specific Product Awareness	This refers to the advertising, through various media, of information about a specific product or set of measures e.g., point of sale literature.
1.3 "How To" Information	This refers to the development and dissemination of information illustrating how to undertake certain retrofit measures e.g., Keeping the Heat In (Publication).
1.4 Hot Line Services	This refers to the provision of advisory services by phone or in person.
1.5 Home Energy Rating	A representation of the energy efficiency of a residential building based either on a set of technical efficiency standards or on a technical tool that assesses the home's energy efficiency in comparison to other homes.
1.6 Identification of Energy Efficiency Opportunities	This refers to the energy performance assessment of dwellings. Types of audits include occupant do-it-yourself (both hard copy and web access) and various degrees of sophistication of contractor-provided audits (e.g., EnerGuide for Houses).
1.7 Testing and Labelling Programs	This refers to the energy performance testing of products and/or dwellings, followed by dissemination of the performance information through labelling.
1.8 Feedback on Performance	This refers to programs that provide more detailed, timely information on the performance of occupants and equipment. An example is the specific breakdown of energy use in customer utility bills.
1.9 Technology Transfer	This refers to the dissemination, with a view towards replication, of information on technologies, measures, and programs through demonstration projects and pilot programs.

2. Regulations, Standards and Codes

2.1 Energy Performance Standard	This instrument sets performance criteria that equipment or complete buildings must meet. With a performance standard, the specific methods and technologies/systems required to meet the standard are left to the discretion of the manufacturer/ designer/ builder. The

	performance standard typically delineates measurement procedures with which achievement of the standard can be assessed.[136]
2.2 Energy Prescriptive Standard	This instrument is similar to an energy performance standard insofar as it sets energy performance criteria that a technology or building must meet. Under a prescriptive standard, however, the achievement of a certain level of energy performance is met via the specification of materials, components, insulation levels, construction methods or other attributes that a product or building must have. Many standards such as ASHRAE 90.1 or R2000 require meeting both prescriptive and performance criteria to achieve compliance.
2.3 Building Energy Code	This instrument is generally a set of regulations that must be followed in the construction of a building. A building code can incorporate energy prescriptive standards with respect to materials and components, or it can specify the overall energy performance of the building.[137]
2.4 Energy Conservation By-Laws	Energy Conservation By-Laws (or ordinances in the U.S.) typically require dwelling vendors to obtain a valid energy inspection and then implement prescriptive or performance-based measures in order to obtain a "certificate" of compliance prior to the transfer of title. In this way, the By-Law brings under the municipality's enforceable jurisdiction some definable performance or prescriptive energy standard.

3. Financial Mechanisms:

(Broadly speaking, this category refers to the provision of incentives designed to stimulate customer behaviour to invest in energy efficiency retrofits. Financial incentives are typically provided in conjunction with information transfer initiatives.)

3.1 Rebates	A rebate is a cash incentive designed to reduce the investment cost of a specific product or set of retrofit measures. Rebates can be targeted to customers, retailers, contractors, and homebuilders. Typically, there are two types of rebate: hardware or prescriptive, and comprehensive or customised. ***Prescriptive rebates*** link the incentive to the purchase or installation of a specified product such as high efficiency lighting products. Prescriptive rebates are generally targeted to encouraging the energy efficiency actions at the time of stock replacement.

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[136] It is important to understand that energy standards and codes by themselves do not necessarily require a mandatory compliance by manufacturers and other affected players in the economy. Typically developed through extensive consultations, these standards are complied with on a voluntary basis until a regulatory authority is established and/or applied, at which point they become regulations. In other words, a legislative based enforceable set of regulations must be promulgated under which specific technical standards and codes will be referenced for compliance.

[137] Marbek Resource Consultants, The Potential for Regulations and Standards to Contribute to Electricity Savings in Ontario, prepared for Pollution Probe's Intervention in the Ontario Environmental Assessment Board Hearings on Ontario Hydro's Demand, Supply Plan, Dec. 1992, p.16.

	Customised rebates link the incentive to the implementation of a set of measures rather than a distinct product. Typically, the customer provides engineering calculations or an audit report to justify the investment, and the rebate is provided on the basis of actual or projected savings (e.g., $/kW, cents/kWh).
3.2 Grants	Grants are cash payments that may be geared to the installation of a specific energy saving measure or bundle of measures. Grants can also be offered to defray either partially or the cost of an energy audit.
3.3 Instalment Purchase/Finance Lease	This refers to a financing mechanism whereby equipment manufacturers or distributors and utilities enable a customer to purchase an energy efficient product through regular payments over a specified term. The payments can be structured so that they are lower than the value of the energy savings attained over the same period. With utilities the payments can be automatically deducted from the bills.
3.4 Lease	This refers to what is often called an operating lease in which the customer makes regular payments for the right to use certain types of equipment e.g., water heater rentals.
3.5 Loans	This refers to the provision of low or no interest "recourse" loans in which the customer provides a full guarantee to the lender for the value of the loan.
3.6 Cash Awards and Gifts	This typically refers to incentives targeted to trade allies. Cash or merchandise is awarded on the basis of sales of specific energy efficiency products.
3.7 Bill Credit	This refers to the provision of credits to customer bills if they participate in specific load management initiatives such as water heater cycling programs.
3.8 Tax Incentives	This refers to the provision of either tax credits for sales, property, and income taxes, or accelerated depreciation allowances for specified types of equipment.
3.9 Innovative Pricing and Rates	Broadly speaking, this category of market intervention refers to the application by utilities of innovative rates and structures to encourage customer energy efficiency and load management decisions.

4. Private Sector Services

4.1 Energy Performance Contracting (EPC)	EPC represents a service in which the private sector provides turn-key services including: energy analysis; design; engineering; construction; commissioning; training; maintenance and monitoring; and financing. Typically the cost of these services is recovered over time as the contractor shares in the actual reductions in

	operation energy costs.
4.2 System Approaches by Renovation Contractors	Renovation contractors will integrate, or have the capacity to integrate, energy efficiency improvements in their work in ways that simultaneously improve comfort, health, safety, durability and convenience.
5. Trade Ally/Distribution Channel Support/Development	
5.1 Capability Building	This refers to the provision of training and certification of service professionals, officials responsible for the design and delivery of programs.

4.2 A LOOK BACK AT RESIDENTIAL MARKET INTERVENTIONS--GENERAL OBSERVATIONS

Over the course of the past 15 years or so, there have been literally hundreds of initiatives directed at the residential sector energy market. The experience base of energy efficiency in the residential sector is substantial. It is rich in scope and creativity and has accomplished much in terms of aggregate energy efficiency improvements. Some of this improvement has been delivered cost-effectively, while other measures have been less successful. These activities have come in virtually every form and approach conceivable, and much has been learned that can help guide the Buildings Table.

Our approach in addressing this issue is to focus on the key observations and lessons learned from past experiences. There are three aspects to this review. First we present an overall summation of the key lessons learned from this wealth of experience. Second, we present some key highlights drawn from periodic profiles and reviews undertaken in the U.S. and elsewhere. Finally, we comment on particular "topics" or issues that are likely to be pertinent as we look ahead to future initiatives.[138]

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[138] Much of this insight is drawn upon reports that have studied the experience of demand-side management (DSM) in the U.S. The considerable body of program reviews to have emerged from this DSM experience is not surprising, given the millions of dollars invested in DSM at the time and the need for most of these programs to undergo third party evaluation.

4.2.1 Summation of Key Lessons Learned

- ***Government and other institutional interventions have been critical to ensuring that social welfare goals were achieved.***

It is very likely that only a small percentage of the energy efficiency improvements achieved to date would have occurred in the absence of market interventions. To understand why this diversity of market interventions has been so critical, it is important for the Buildings Table to consider how energy efficiency can be generated in a given market situation.

Three things can happen to increase the impact of energy efficiency measures:
a.) Acceleration of the pace at which energy efficiency occurs in the market;
b.) Expansion of the unit impact of measures (i.e., the savings); and
c.) Expansion of the market for energy efficiency initiatives.

Each of these dimensions is discussed below.

Acceleration of the pace of investments: Market interventions have been very successful at achieving this goal. The primary "driver" has been an assortment of financial incentives that have served to reduce the payback on energy efficiency investments to a level where customers decided to make the purchase. While grants were initially the preferred choice of incentive, rebates subsequently became by far the most common form of incentive, primarily through utility programs. Coupled with the incentives have been activities designed to promote programs and to increase awareness, as well as efforts to "partner" with the trade allies developing and delivering the energy efficiency products and services.

Expansion of the unit impact of measures: Great strides have been made in the technical impact of energy efficiency measures, both in terms of individual measures, as well as efforts to develop integrated, comprehensive approaches. Market interventions have been instrumental in achieving these advances. Research, development and demonstration activities have laid the foundation for market deployment of advanced equipment, tools, techniques and materials. Training and certification initiatives have been instrumental in helping to ensure that the initial savings impact of measures is sustained for its useful life. Finally, energy performance standards, both in terms of equipment and building codes, have served to eliminate very inefficient products and building practices from the marketplace and also, by virtue of the process of developing these levels, have helped inform the market of opportunities to advance performance beyond the minimum.

Expansion of the market for energy efficiency: This last category refers to those opportunities to expand applications of energy efficiency in the residential market. Again, government and utility-sponsored research, development, and demonstration activities have helped identify these opportunities.

- ***There has been a transformation in the residential energy marketplace:***

  As the Buildings Table considers options to increase the impact of energy efficiency, it is important to consider that today's energy efficiency marketplace differs considerably from that of 10 to 15 years ago. Understanding these differences is critical to establishing an effective near-and longer-term strategy. Essentially, there has been a transformation in the market embodying the following key characteristics:

  i. The availability of many energy efficient products is now the norm, rather than the exception. This includes lamps and ballasts, appliances, and furnaces.

  ii. The price premium on many energy efficient products has either been reduced or disappeared altogether. High efficiency windows represent one such example.

  iii. There now exists a well-trained infrastructure of energy efficiency suppliers.

  iv. There are new private sector service offerings that help package financing and services. Examples include energy performance contracting and third-party non-recourse financing.

  Ultimately, the most critical change in the marketplace has been the move towards restructuring and deregulation in the energy supply markets. While the final effects of this profound change are uncertain, we do know that the way in which consumers purchase energy and the way in which energy is supplied and marketed at the end-use level will be different than what it was before. Deregulation will likely lead to lower energy prices for the consumer, which will undermine the cost effectiveness of energy efficiency measures.

- ***Market interventions have still fallen short in key sub-markets:***

  The market penetration of energy efficiency has been far more pronounced in the single detached portion of the residential market than in other areas of the housing sector. There has been limited impact in key sub-markets such as low-income and tenanted households, both at the low-to high-rise type of building structures. Another critical area where past market interventions have fallen short is in what is referred to as the "lost opportunities" segments. This refers primarily to new construction or major renovation opportunities where energy efficiency can be effectively piggy-backed onto construction activity that is already occurring.

- ***Market Interventions Don't Always Pay Off***

  Interventions have not always paid off, resulting in the cost of delivery sometimes being higher than the cost of the energy form being displaced. Underlying such performance issues has been the critical issue of "incrementality"; that is, the notion that interventions in the marketplace should foster actions that would not have been undertaken in their absence. Those participants in market interventions who would have taken the energy efficiency actions anyway are referred to as 'free riders'. Governments and utilities have invested large amounts of money to measure incrementality and free-ridership.

Financial incentives have induced accelerated energy efficiency activity but not always in a cost-effective manner. Free-ridership has been significant when measures with relatively short paybacks have been promoted and when measures have had high market shares.

Consumer and other information initiatives do not generally pay off with energy efficiency investments unless explicitly linked to the means of ensuring implementation. Over twenty years of continuing market interventions through large scale, mass information campaigns has produced little definitive evidence of success in changing attitudes or energy efficiency investments. While it is likely that public sympathy for greenhouse gas emission investments will be higher than for saving energy due to the risk of environmental costs, it is unlikely that information campaigns on their own will stimulate significant investments or changes in behaviour.

4.2.2 A Summary of Energy Efficiency Market Intervention Experience

This section presents a "snapshot" of what has been learned from energy efficiency program experience, using the observations from previous compilations of initiatives in this area. In particular, we focus on the work of the American Council for an Energy Efficient Economy (ACEEE) in documenting the experience and impacts of utility demand side management (DSM) initiatives. Although much of the ACEEE review is focused on utility DSM initiatives, the observations are generally applicable to market interventions as a whole. The ACEEE completed several reviews that corresponded to the evolving approaches and activities of the utilities in the residential market.

The First Round of Utility Demand Side Management (DSM) Program Review[139]

The first review, which followed the early period of DSM initiatives, noted that, despite the accomplishments generated by these programs, there was a substantial need for improvement in three key areas:

- Reduced levels of free-ridership (i.e., energy efficiency investments by program participants that would have been undertaken in the absence of the market intervention);
- Increased savings and sustainability of the savings; and
- Increased penetration rates.

The ACEEE also made the following key observations:

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[139] Electric Utility Conservation Programs: A Review of the Lessons Taught by a Decade of Program Experience

Lessons Learned from Utility DSM Programs

- Energy audits alone generally result in only limited energy savings.
- Different program approaches fill different niches.
- Marketing strategies and technical/construction support services have a large impact on program participation and services.
- Financial incentives tend to increase program participation and savings.
- Lost opportunity resources (which occur, for example, when buildings are remodelled or change hands) should be considered.
- Free ridership is greater when measures with rapid payback periods are promoted and when measures have high current market shares.
- Measured savings from residential retrofit programs are often less than engineering estimates.
- Association with top-notch trade allies is essential.

The Next Round of Review

In the early 1990s, utilities started to reduce their financial commitments to DSM. Certain components of the energy efficiency market had begun to transform in such a way that the same levels of financial incentives were no longer thought to be critical. As utilities moved to reduce budgets, the ACEEE put forward elements of a "least cost strategy" in which energy efficiency could still be delivered with strong results[140]:

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[140] Nadel, Stephen. Providing Utility Energy Efficiency Services in an Era of Tight Budgets: Maximizing Long-Term Energy Savings While Minimizing Utility Costs. American Council for an Energy-Efficient Economy, Washington, DC., July 1996.

Six Key Elements of A Least-Cost Energy Efficiency Strategy

1. Foster market transformation where possible, so that efficient equipment and designs become the norm.
2. Address lost opportunity resources by targeting energy-related purchases that are already happening in the market for efficiency upgrades.
3. Build loyalty of potentially mobile customers by offering enhanced but moderately priced services including energy efficiency services.
4. Expand programs that lower rates, such as load-management programs and programs that can defer transmission and distribution investments
5. Offer limited retrofit programs targeted at customer segments that are least likely to share in the benefits of increased competition, such as low-income households

Experiment with new energy efficiency strategies, particularly strategies that can perhaps be operated at a profit or at least may have lower rate impacts than traditional energy efficiency programs

Other Observations

In this section we touch on additional observations that have emerged either from direct program experience or other research and analysis.

- **Information Campaigns and Their Limitations**

  In general, there have been few comprehensive assessments of consumer information campaigns, but those that have been completed indicate that the impact has been limited.

  A review of consumer education activities undertaken by EMR in the mid-1980's examined the impacts of three types of initiatives: the "Heatline"information service, various publications, and marketing campaigns. The results indicate that retrofit take-up after receipt of these types of information is confined to well-educated middle- to upper-income groups. As well, the energy efficiency measures were confined to no-cost and low-cost actions.

  Among the most recent assessments of this approach to energy efficiency was an analysis of the Wisconsin Electric "Energy Conservation Campaign", introduced in 1997. When measured in terms of "stated intentions", it appears that the mass campaign resulted in a sufficient change in behaviour such that surveyed households indicated potential actions for showerhead and water tank efficiency installations.[141] Again, this serves to underscore the difficulty in moving from energy efficiency awareness to action.

- **Stop focusing on individuals – instead focus on communities of people with similar values and concerns**

  A recent dialogue among researchers from the social and physical sciences concluded that the wide range of models and means of characterising sectoral energy use patterns and targeting market interventions are limited in that virtually all of the approaches focus on the characteristics and properties of the individual consumer. They go on to suggest that we should perhaps be rethinking, or reframing the way in which we market to the residential sector.

  They note that, under current approaches, " *people are, by implication, relatively free agents, each choosing how much energy to use in their daily lives. Wrapped up in this paradigm, modelling involves the representation of beliefs and values, or taken one step back, of the packages of beliefs, cultures or lifestyles thought to drive individual action. This representation strips people of any social identity, and*

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[141] Peters, Jane; Ken Seiden, Sharon Baggett, Lyn Morander, " Changing Consumer Attitudes to Energy Efficiency: Midterm Results from an Advertising Campaign" in American Council for an Energy Efficient Economy 1998 Summer Study in Buildings, p.8.259

abstracts energy consuming practices from the situations, both economic and physical, in which they take place."[142]

So where do we go if this observation is at all accurate? The ACEEE paper goes on to suggest that it is necessary to go beyond the individual consumer (households or their members) and start addressing the interest and actions of influencers and decision-makers, such as policy makers, designers, the media, distributors, and others "implicated in the structuring of choice and fabrication of possibilities.

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[142] Harold Wilhite and Elizabeth Shove, Understanding Energy Consumption: Beyond Technology and Economics" in ACEEE Summer Study on Buildings, 1998, p.8.326.

- **Develop special policies and initiatives for reaching the "slippery" segments such as multi unit residential buildings and low income housing**

As profiled in Section 2, a segmentation of the residential sector includes historically "tough nuts to crack", such as multi-unit residential dwellings and, in particular, the low-income groups within this category. Over the years a variety of institutions, particularly in the U.S, have sponsored activities in this sub-market. The types of market interventions have also varied and have included:

i) fuel rate discounts,
ii) direct installation,
iii) energy education and awareness, and
iv) audits.

Target markets have included both the building owners and renters. For example, one initiative was actually targeted to mobile homes, and another involved a labelling service for dwellings that had been retrofitted (the WHEEL initiative in Wisconsin).

There continue to be many challenges to working with this sub-market. Working with community-based organisations can be time consuming and expensive. However, recent experience with Green Communities in Ontario has demonstrated that low income household can be reached in an efficient and cost effective manner. Frequently a sizeable portion of the costs of these programs is borne by building owners, such as social housing agencies, who reap the benefits of the programs.

The few rigorous evaluations that have been undertaken indicated that savings are generally found to be persistent. To help ensure the sustainability of savings, education is a vital component. However, when viewed as a percentage of estimated savings, actual savings were significantly greater in owned rather than in rented homes. Those initiatives that have involved community groups and participation suggest that this "model" helps secure a commitment to the program. Whatever approach is used in this target sector, there is a need for a strong and well-targeted marketing approach followed immediately by follow up services.

- **The Experience of Home Energy Ratings**

As noted in Appendix A, the federal government has launched a national home energy rating initiative, "EnerGuide for Homes". We present some observations from early thrusts in this area. Specifically, evaluations of Home Energy Ratings (HERS) programs have indicated that :

1) The level of sponsor commitment and resources is a key factor. Even in the absence of financial incentives, sponsors must be prepared to finance the program until it achieves a critical mass);
2) There is a need to avoid conflicting goals that compromise the overall effectiveness of the program. (HERS have been launched for many reasons, e.g.,

to leverage utility DSM programs, and to provide jobs and social assistance schemes);

3) The ratings must attain credibility with customers and stakeholders, yet at the same time be technically sound and measurable;

4) The HERS must be closely linked to energy efficiency services, so that homeowners can make investments with a low level of administration overhead and as part of a streamlined process.

- **The Experience of New Construction Initiatives**

Some lessons can be drawn from a recent review of utility initiatives for new homes, as well as from the federal government's evaluation of the R-2000 program.[143]

The utility review was focused on the commercial sector, but is pertinent to the high-rise multi-family sub-markets. The general goal of utility new construction initiatives has been to "*make energy efficiency improvements a routine and essential part of the process for designing/constructing new buildings and for doing major retrofits*". Utilities offered demonstrations, technical design assistance, information transfer, and financial assistance for both incremental design and construction costs. Overall, these initiatives exhibited a high level of free-ridership. The custom approach to development of energy efficient buildings generated higher program participation than for prescriptive approaches.

The R-2000 program evaluation has revealed the following:

- The program was cost-effective from the government's perspective.
- The program exhibited only very limited market penetration but **indirect impacts were assessed to be very high**. It was an effective vehicle for bringing new technology and construction practices into the market. Many of the recent improvements in energy efficiency of new buildings can be directly attributable to the technologies and practices promulgated by the R2000 program (such as improved air tightness, use of heat recovery ventilators, and so on.)
- The incremental cost of building to R-2000 standards and levels is only approximately 2 to 4% greater than the cost of new homes built to 1995 National Building Code Standards, However, incremental costs were viewed by all players in the market as the singularly most important barrier to increased take-up.

4.3 NEW ACTIVITIES AND MARKET TRANSFORMATIONS

In this section we provide a "snapshot" of current market interventions in the residential market. We begin with an overview of how the approach to energy efficiency has changed, due, in part, to the emergence of power sector restructuring and deregulation. We then highlight some of the key characteristics of the interventions that are presently occurring in Canada, commenting on the link between the past and the present.

To supplement this discussion, we also present in Appendix 3-A a summary of many of the current Canadian energy management initiatives in the residential sector. While this profile is by no means fully comprehensive, it does illustrate the type of market interventions currently being offered, particularly at the federal level. With regard to the government, the profile illustrates the following:

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[143] Marbek Resource Consultants, Profiles of New Construction Energy Efficiency Programs, prepared for NRCan, July 1997. And ARA Consulting Group Inc., Marbek and Scanada, Evaluation of the R-2000 Program, prepared for NRCan, 1995.

- Both mandatory and voluntary energy performance standards and certification continue to represent an essential "foundation" role of the government. At the federal level, this role continues to be important in the context of helping to achieve harmonisation among the provinces. The publication of the Model National Energy Code for Houses (MNECH) is starting to be an important catalyst in gaining provincial acceptance of advanced levels of building energy performance. As an example, the Province of Manitoba has integrated many of the MNECH's prescriptive requirements, and an option for using its performance method in their new provincial building code.

- Canadians have already accepted energy efficiency regulations for new housing. Although it is not widely acknowledged, minimum energy efficiency standards for buildings are already included in most building codes, and have been so for a long time. The provinces of BC, Alberta, Manitoba, Ontario, and Quebec already have minimum energy efficiency regulations for new homes. As a result, 9 out of 10 new homes built in Canada already must meet the requirements of energy efficiency construction regulations.

- The deregulation of the utility industry is expected to lead to lower energy prices in the future, devaluing the cost effectiveness of energy efficiency improvements.

- Energy performance labelling continues to be an important means of trying to influence consumer purchase decisions; labelling initiatives now extend beyond appliances and windows to include the recently launched EnerGuide for Homes initiative.

The utilities are employing a range of approaches directed at the residential sector. Their initiatives include:

- Direct installation of higher efficiency products;

- Partnerships with contractors and lenders to offer full service packages;

- Advisory services to customers;

- Promotional collaborations with trade allies.

4.3.1 A Transition Towards Market Driven Services

As noted above, it is evident that utility and government intervention in the market has been the primary driver behind the energy efficiency improvements achieved in all sectors of the economy. Both of these entities continue to intervene actively in the residential sector market. However, the approach to intervention has changed noticeably within the past five years or so. This change has been characterised as a transition from **purchased**

conservation to **market transformation**. Today, with the advent of power sector restructuring and deregulation, utilities are far more committed to offering energy efficiency services that focus on market transformation.

The concept of purchased conservation emerged from the thinking that, in an undeveloped energy efficiency market, there is a need for financial inducements (coupled with other non-financial initiatives) to develop a demand for and provide the basis of a supply of energy efficiency services/products. This was the initial approach taken by government programs (e.g., the Canadian Home Insulation Program) and utility demand side management (DSM) in North America, and resulted in millions of dollars of direct transfer to customers being invested by utilities. There are some who believe that the purchased conservation approach fell short of achieving its intended impact because, in part, financial incentives created a dependency in the market, and when the incentives were phased out some market barriers still tended to inhibit appropriate investment in efficiency.

As the market for energy efficiency services and products began to become more mature, utilities and governments realised that the previous levels of financial inducements were unnecessary to stimulate customer investments in DSM. New and more subtle approaches emerged under the guise of market transformation (e.g. establishing strategic alliances with trade allies). This approach aims to permanently address the market barriers to DSM, thereby making a longer lasting change to the energy markets.

Perhaps this transition is more heavily pronounced in the utility sector, because that's where the greatest shift in emphasis has been seen, but government interventions have also tended to reflect this trend. In any case, at the present time both governments and utilities offer primarily what they present as market transformation approaches to DSM. However, they also continue to use purchased conservation on a selective basis, for market segments that are characterised by particularly difficult barriers to DSM take-up.

Perhaps the singularly most exciting and challenging aspect of DSM in a reformed power sector is that many utilities have begun to investigate or start delivering broad service offerings that extend significantly beyond the traditional goals of reliable and economic power delivery.

In particular, energy services are seen to be a platform for launching an increasingly broad range of "value-added" services, ranging from communications to 'whole-house' solutions that deliver products with credit financing. In the last several years the Canadian energy service market has experienced many new entrants, including US utilities, gas utilities with new offices across the country, automobile insurance companies, big box retailers, coalitions of independent contractors and so on.

It appears that the most rapid diversification of service offerings is in the area of enhanced communications. These service offerings are based on the premise that customers have a growing need for more information at a more rapid pace (e.g., real time). The information needs may link to electric power, (for example, real time prices to correspond to an ever-increasing array of price options), or may link to other utilities such as telephone services. These service offerings have led to collaborations among different types of utilities, software developers, and hardware providers. Some examples of potential enhanced services, directed primarily to the low-rise residential sector, include:

- Utility changes price hourly and transmits changes to customer via telephone and RTF with thermostat as interface. Appliances are programmed only to operate at certain price levels.
- Homes are connected to broadband system where lighting, security and set-back are controlled.
- PCs are used as an interface for enhanced services using telephone lines/internet, and PLC.

4.3.2 New activities carefully target market barriers

The current and emerging interventions in the residential market exhibit the following key characteristic:

> *They are increasingly directed towards addressing specific market barriers with the goal of accelerating market transformation.*

Table 4.2 provides one such example, demonstrating how one of the leading U.S. electric distribution utilities has established a DSM portfolio that is driven by the goal of addressing market barriers. The Table shows a couple of examples from their portfolio.

TABLE 4.2 MARKET BARRIERS AND RESPONDING PROGRAM STRATEGIES FOR TWO STRATEGIES - COMPACT FLUORESCENT LIGHTING AND IN-HOME SERVICES

Market Barriers	Strategy Details	Strategy Rationale
1. Compact Fluorescent Lighting		
Lack of consumer awareness	· Develop a major product marketing and education campaign. · Co-ordinate marketing activities with manufacturers/other utilities.	· Consumer awareness/acceptance is a key goal. According to the program's most recent process evaluation, about 37% of customers are still unaware of CFLs.
High first cost	· Provide strategic rebates as determined by market research and market response. · Use joint-utility volume commitments to enlist/require manufacturer contributions and other concessions to lower utility and customer product costs.	· The first cost of CFLs is 10 to 20 times higher than the incandescents they replace.
Lack of vendor familiarity/program inconsistency	· Work with other regional utilities to develop a joint-utility program with well documented plans and commitments. · Utilize regional circuit riders to enlist and maintain retailer participation in the program and educate them on program details, products, etc.	· Inconsistent and variable product and program information provided to retailers and manufacturers, combined with program support uncertainties, reduces interest and commitments to individual efforts.
Other	· Continue yearly market research to test assumptions and refine program elements as needed. ·	· Other market barrier may be unknown and/or of misunderstood significance.
2. In-Home Services		
Lack of consumer liquidity and reluctance to borrow.	· The utility company invests to replace inefficient equipment for low income customers, and provides rebates to customers with higher incomes.	· Energy efficiency services are important tools for bringing bills down to manageable levels and cushioning lower income customers from the impacts of market-based pricing on affordability.
No incentive for tenant to improve landlords' property/No incentive for landlord to invest if tenant pays utility bill	· The utility company invests to replace inefficient equipment. Non-occupant landlords pay up to 25% of the cost of major equipment replacement.	· The split incentive that is inherent when the utility bill payer is different from the property owner creates difficulties in capturing energy efficiency opportunities.

Market Barriers	Strategy Details	Strategy Rationale
Low-income households generally have less education/less awareness of cost savings energy investments	· The programs are built around an interactive educational approach and offer information designed to answer customers' questions and encourage understanding of possible energy conservation actions.	· Appliance-specific education and savings estimates assist customers in choosing what appliances to run and how often.
Lack of consumer awareness of efficient appliances, lighting, and building technology	· Provide one-to-one education to encourage the replacement of inefficient equipment. Provide rebates or subsidized installation to ensure that all cost-effective measures are installed.	· Some consumers may need additional customer-specific information and counselling in order to invest in energy efficiency.

4.3.3 Strategic alliances and risk sharing are becoming much more common

There is growing evidence of strategic alliances and risk sharing among key players in the market, including government, utilities, service providers, and the financial community. The key appears to be recognition of the strengths that each brings to the market and also an understanding of what each hopes to gain by participation. For example, the utilities recognise the role of government in promulgating equipment energy performance standards. The standards provide a foundation for other interventions in the market. Financial institutions can benefit from customer access to renovation financing. Energy utilities can use their customer base and reputation to generate leads and, can benefit from enhanced customer loyalty, and new revenues. This co-operative approach enables the following to be achieved:

- Impact on a larger share of the market
- Buy-in from all key players
- Sharing of cost and risk
- Increasing role for the private sector in delivery of energy services
- Increasing role of the lending community in helping to address the financing barrier to energy efficiency.
- Benefits for local communities in terms of job creation, community economic development, and an improved quality of life for participating homeowners.

An interesting "model" which employs a shared risk approach is through the Toronto "Better Buildings Partnership". The BBP was launched by the City to help it meet its official GHG emissions reduction commitment. The BBP is a partnership involving the City, the Toronto Atmospheric Fund, Toronto Hydro, and Consumers Gas. The program has to date committed projects totalling over $38 million, primarily in the non-residential buildings sectors. However, now the City is looking towards expanding its BBP activities to the residential sector, with a particular focus on multi-unit dwellings. The City is looking to develop a "revolving environmental loan fund" to provide low interest loans and/or investments for energy and water efficiency retrofits. Under this approach, building owners would apply to Consumers Gas for loan financing and repay loans on their gas bills. In the event of a default, the utility would access the loan recourse fund.

Some additional examples of these shared risk and partnership approaches are presented below.

4.3.4 The Lending Community is Becoming More Active

For many years government and utilities played the role of financial lender to the energy efficiency market. For the most part, the lending community stayed in the background with some involvement in the leasing of equipment. Over the past five years or so, however, this situation has begun to change significantly. Governments and utilities have come to realise that lending money is not their primary business or role. The emergence of energy performance contracting as a legitimate and major service in the energy efficiency market has played a large part in this shift. Many performance contracts are now financed by the lending community.

Banks and leasing companies are working with key trade allies to deliver customised service offerings or simply embed energy efficiency in their broader service packages. Several lenders offer mortgages and loan packages that provide lower interest rates for energy efficient new construction. For example, the Canada Trust "EnviroMortage", which offers a 2 % cash bonus on the principal for certified R-2000 homes.

Perhaps the most significant initiative presently occurring in the residential sector has been the development of third-party, unsecured and non-recourse financing for energy efficiency investments. Operating much like a car loan, contractors can sign up customers for financing on an energy efficiency job, with the financing to be provided by a lending institution. The Toronto Dominion "Green Lights" initiative is one leading example of this approach. TD has been operating this service since 1993 and has partnered with six electric and gas utilities across Canada. Initially, the program worked extensively with equipment suppliers, helping to finance new HVAC products. However, the service is now moving into the retrofit business.

4.3.5 Energy Performance Contracting (EPC) Still Has Achieved only Very Limited Market Penetration

In Canada EPC has been successfully implemented, but to a very limited degree in multi-unit residential facilities, condominium high-rise buildings, nursing homes and seniors' facilities, and social housing. High business development and transaction costs make this a riskier market for the energy services industry. EPC, in its current form, is best suited for large residential customers in the area of annual energy bills that exceed $200,000, and where the owner has the resources to invest in a long-term relationship with an Energy Service Company (ESCO).

In the U.S., where residential sector EPC activity has been more active, the primary driver has been the involvement of utility demand-side management (DSM) programs that offered financial incentives and/or information and technical support. As utility financial support for DSM has been reduced or completely phased out, ESCOs that still operate in the residential market have refocused on the mid-to high-rise social housing markets, as well as high rise rental buildings.

4.3.6 Community Based Approaches are Making a Come-Back

As a result of increased community involvement in resource and infrastructure planning, local initiatives are becoming more common. These may address local needs for job creation, affordable housing, power scarcities, air quality, and sustainable development. One example is the Green Communities Association (GCA) that is promoting energy efficiency at the local level in a number of Ontario communities. The GCA is in the process of expanding the Green Community model to communities in other provinces.

Green Communities (GC's) are community-based non-profit multi partner environmental organisations that benefit the environment, save money, and stimulate spending on green products and services. GC's offer cost-effective solutions to environmental issues by bringing together various sectors of the community in an integrated fashion to achieve common environmental objectives.

Green Communities offer a variety of services to improve energy efficiency in the residential sector, including direct installation of conservation products, weatherization services, and "Green Home Visits". These are comprehensive residential assessments conducted by professional advisors who work with householders to identify ways to save money, improve comfort, and reduce environmental impacts. Householders are offered access to qualified contractors, preferred rate financing through lending institutions such as Canada Trust and TD Bank, and discounts on recommended products and services. The GCA was recently licensed by NRCan to deliver the EnerGuide for Houses program in Ontario.

5.0 WHAT POTENTIAL POLICIES AND PROGRAM OPTIONS CAN HELP TO ACHIEVE THE ECONOMIC AND TECHNICAL POTENTIAL?

5.1 INTRODUCTION

On the basis of the analysis from Chapter 3, it would appear that substantial opportunities exist for reducing GHG emissions through a range of technological and behavioural change options. Further, there is abundant information that suggests that many of these opportunities are currently economically feasible. However, the existence of technical and economic potential alone does not guarantee that such potential will be realised.

This chapter takes the lessons learned from previous policies and programs and examines policy options available for turning the technical and economic potential into achievable potential. Market and attitude barriers to achieving the technical and economic potential for reduced GHG emissions are described, and a framework for evaluating the potential effectiveness of policy measures is presented. Research on the achievable potential for GHG reductions for each category of measures is summarised, followed by an assessment of the potential effectiveness of individual measures specific to the residential sector in the context of barriers and the evaluation framework.

5.1.1 How can we estimate impacts of specific policies?

Over the past twenty years, there have been hundreds of research papers on the topics of energy use, energy conservation, and the environmental impact of energy[144]. Almost every aspect of the problem has been studied, including numerous estimates of technical, economic and achievable potential; cultural factors affecting energy use and GHG emissions; and the least-cost policy options for dealing with the efficiency gap and GHG mitigation.

Despite the passage of time, however, fundamental issues that were central to the debate twenty years ago remain unresolved. A wide diversity of opinion remains in the literature regarding the most effective policy mechanisms for achieving reductions in GHG emissions. At one extreme is the view generally associated with economists and rooted in the concepts of consumer sovereignty and rational choice. At the other extreme is the work of behavioural researchers and technological analysts who perceive the decision-making process of consumers to be inconsistent with the economic concepts of rationality and utility maximisation.

It is argued that disagreement over the facts and models is a central characteristic of the policy debate related to energy efficiency and GHG reductions. In this context it is worth identifying three controversial issues:

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[144] Lutzenhiser, L., A Cultural Model of Household Energy Consumption, Energy, Vol. 17, No. 1, pp. 47-60, 1992.

1. **Top down vs. Bottom up** - Both the economic or "top down" approach and the technological or "bottom up" approaches to modelling achievable potential have limitations. For example, the focus of the top down approach on opportunities assumes that economies are operating efficiently. Top down approaches, therefore, cannot directly deal with the issues of energy efficiency improvements or fuel switching, since by definition no such opportunity exists in an efficiently operating economy. Likewise, bottom up approaches are concerned primarily with the technological and economic potential of individual technologies and measures, without explicit treatment of how changes to one part of the economy might affect another part. Therefore, bottom up approaches typically overestimate the potential for GHG emission reductions in an economy. Due to the limitation of both approaches, there is a strong argument for using both simultaneously. No single model can describe this policy issue unambiguously and completely.

2. **Population Growth and Levels of Activity** - Many studies that explore the opportunity for reducing GHG emissions stay clear of whether policies should be developed to reduce the activity level of consumers (for example, number of households and appliances, size of homes, etc.). It should be noted that the single largest factor contributing to continued increase in GHG emissions in the residential sector is continued growth in the level of activity. Based on analysis by Natural Resources Canada[145], the 6.2% increase in CO2 emissions between 1990 and 1996 can largely be attributed to the 11.9% increase in the level of activity (measured in terms of floor area).

3. **Using Energy as a Surrogate for GHG Emissions** - It is important to recognise that there is not always a constant relationship between improvements in energy efficiency or fuel switching and GHG emissions reductions. Stated differently, policy that reduces energy consumption may or may not result in GHG emissions reductions. This presents a challenge in the context of the current work, as many studies that examine the achievable potential in an economy do so from the point of a particular energy carrier like electricity.

5.1.2 What is difference between Technical, Economic and Achievable Potential?

The potential for reductions in GHG emissions is frequently defined in terms of the technical potential, economic potential and the achievable potential.

The *technical potential* refers to the reductions in GHG emissions that could be achieved in a specified year assuming implementation of the most efficient technologies, regardless of cost. The concept is static, because it only includes current estimates of available technologies.

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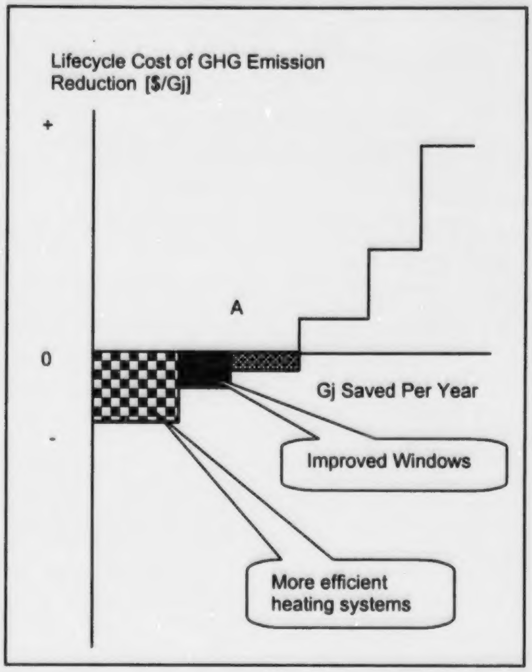
[145] Natural Resources Canada, Energy Efficiency Trends in Canada, 1990 to 1996, Ottawa, Ont. Pg 14, June 1998.

Economic potential corresponds to the savings in GHG emissions in a specified year that could be achieved through the implementation of available technologies that yield a net monetary savings to the key decision-maker, or to society as a whole. Economic potential can be difficult to estimate partly because of the unequal sharing of benefits (those who pay the costs may not receive the benefits), and partly because it is difficult to establish monetary values for many social goods. Another difficulty with estimating economic potential is that cost estimates for new technology are notoriously unstable —as new policies increase the market size for a product or service, the unit costs can drop dramatically and the economic potential improves.

Achievable potential is the set of economic technologies that will likely be adopted under a given set of policies.

Technical and economic potential can be mapped using a cost benefit curve similar to that shown in Figure 5.1. The challenge in developing policy is to capture all the opportunities that lie to the left of point A. If further reduction is necessary, the goal of the policy is to capture portions of the curve that do have a net cost to society, but at a cost that is reasonable given the risks associated with climate change. In the long term, the challenge for policy is to shift the curve downward and to the right so that further GHG reductions can be achieved at (relatively) lower costs.

Figure 5.1 - Example Cost Benefit Curve For GHG Emission Reduction Opportunities



The existence of economic potential, however, does not guarantee that such potential will be achieved. Achievable potential consists of the economically achievable measures that are likely to be adopted for a given set of policies. The experience of energy efficiency programs over the last twenty years is that typically, only 10% to 15% of the economic potential is realised, even with the presence of energy efficiency programs[146]. This in turn leads to what has been referred to in the literature as the Achievability Gap. The Achievability Gap explains why it is not – as some would argue – sufficient to adjust the price of energy to reflect the true costs of climate change, and then simply let the market respond

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[146] Robinson, J.B., The Proof of the Pudding: Making Energy Efficiency Work. Energy Policy, Vol. 19, No. 7, pp. 631-645, 1991.

5.2 BARRIERS TO OVERCOMING THE ACHIEVABILITY GAP IN THE RESIDENTIAL SECTOR

It is important to understand the underlying causes for the divergence between residential sector economic potential and achievable potential for reducing GHG emissions if policies and programs in Canada are going to achieve GHG emissions reduction targets. As noted in the Canadian National Action Strategy on Global Warming[147],

> *While many energy efficiency improvements already make sense in their own right, they will not occur because of market barriers to their adoption or individual decision making. Innovative government actions will likely be required to achieve significant levels of adoption.*

On the energy *demand* side, there is a clear divergence between the amount of energy efficiency improvements or GHG reductions that are cost effective, and the amount that occur through market forces alone. On the energy *supply* side there are also a number of distortions that imply that the fuel mix in Canada diverges from what is socially optimal. There are a number of market failure barriers and market friction barriers that can explain this divergence in the residential sector, as described below:

5.2.1 Market Failure Barriers:

Externalities - The real costs of CO2 emissions and other environmental impacts are not easy to capture in the market place, because they are difficult to predict, and because so many people are affected that the transaction becomes impractical. Costs are thus externalised, and this leads to incorrect price messages and market distortions. Environmental externalities are also not consistent across energy sources (such as coal-fired generation versus micro-hydro). Further, the presence of taxation, royalties, rents and subsidies means that the cost perceived by the industrial decision-makers are distorted, and do not result in the socially optimal fuel mix.

Bounded Rationality (Irrational Consumer Behaviour)- Consumers behave differently than what would be expected in that they do not necessarily make the most economically rational or economically optimised decisions.

Inconsistent Information - Builders and consumers often do not have access to the same information as utilities and government organisations and so they make second best energy efficiency decisions.

Monopolies - The monopolistic nature of the energy supply sector distorts the market.

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[147] National Action Strategy on Global Warming, Ottawa, Ont, November, 1995, Pg 27.

5.2.2 Market Friction Barriers

Uncertainties

Uncertainties in future energy prices, impacts of global warming, the chances of technological breakthroughs, and so on affect consumer's evaluation and decision-making processes.

Transaction Costs

The time and costs associated with identifying and obtaining advanced energy efficient products and services also serve as an impediment.

Consumer Attitudes that make energy a low priority

Canadian Homeowners do not place a high priority on improved energy efficiency in their homes. Most are concerned about the environment and are practising simple energy conservation measures such as turning off lights or turning down the heat. However, they do not regard energy retrofits in their homes as a high priority since they believe that they have already done their share and their homes are already above average in energy efficiency[148]. When renovating, their main priorities are functional improvements (comfort, kitchens, bathrooms, etc.), additional space, and improvements in appearance.

Although most Canadians rate themselves favourably in their knowledge of energy conservation, they have little knowledge of where their energy comes from, and the link between energy consumption in their homes and the resulting greenhouse gas emissions.

While energy represents a small fraction of housing costs for some Canadians, it represents a significant portion of housing costs for many low-income households, seniors, persons with disabilities, and northern/remote residents. These are the populations that are also the least able to afford energy efficiency improvements.

Energy Invisibility

The invisibility of energy is frequently argued as a major obstacle to improving efficiency. Because of energy's invisibility, individuals may develop "folk calculations" to provide information on estimates of energy efficiency. These calculations may be based on running time or estimates of the amount of human labour replaced. Such calculations contribute to sub-optimal energy choices[149].

Homeowners and tenants often do not know how much energy they are consuming at the building level (especially in non-individually metered apartment buildings), let alone at the individual service or equipment level. Energy is delivered directly into our homes with no participation required on the part of the homeowner to collect, deliver, or refill the fuel supply.

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[148] Natural Resources Canada and CMHC, Home Energy Retrofit in Canada, Overview and Opportunities, p. 28, 1994

[149] Lutzenhiser, L., Social and Behavioral Aspects of Energy Use, Annual Review of Energy and the Environment, Vol. 18, pg.261, 1993.

Homeowners have poor knowledge of the energy performance of their homes. While consumers expect, and manufacturers provide, information for comparing the performance of many consumer goods such as the power and energy efficiency of automobiles, manufacturers generally do not provide information about housing that will allow the consumer to compare the energy efficiency (or other areas of performance such as comfort, ventilation, durability, etc.) of one home to another.

A Lack of Clear, Credible Information

Energy information may present a barrier to behavioural changes in conservation. A major problem with energy information is that it is often presented in ways that are unfamiliar or abstract to homeowners and decision-makers. Instead of information being provided in the form of a simple index of efficiency, it is frequently given in scientific units that may have little or no meaning to the user.

A second problem with energy information is the diversity within the target audience. Because there is a great diversity among buildings and energy users, information directed towards an *average* building or consumer is probably going to be incorrect for any *specific* building or user. This variability creates great uncertainty about the accuracy or value of information provided.

A further problem with energy information is the confusion and loss of credibility of experts created by conflicting advice and policies. An example of this may occur when utility companies promote the conversion of heating systems from electricity to gas as a means of saving on energy bills, while ignoring that electricity-powered heat pumps are highly efficient for space conditioning. Implicit in this problem is the need for credible, accurate and non-biased sources of information. People respond not only to information, but to their perceptions and evaluations about the source of information. Unfortunately, many organisations such as builders or utilities lack credibility among their customers. It becomes a difficult task, therefore, to penetrate a market with information, even if that information is correct.

High Discount Rates

A common problem among consumers considering improvements to energy conservation equipment is the high discount rate they implicitly place on their investments. Building owners do not look at life cycle costing realistically, and therefore expect immediate return on energy efficiency investments. In one study, a range in implicitly demanded discount rates from 20% to 200% was observed. [150]. The consequence of this is that many investments do not appear economically viable to these consumers. For example, high efficiency lighting systems have higher capital costs than regular lights, but over their expected life the investment will save money. If the discount rate used by an individual is high, the investment in efficiency will not be attractive.

The most likely explanation for this is a feeling of insecurity among consumers, along with uncertainty in future energy prices, technological advances, and so on. Canadians are highly mobile, and have a general sense of job insecurity. As a result it is probably unrealistic to expect people to buy into the concept of ten-year paybacks.

Momentum of Past Behaviour

Altering the inertia of past behaviour is often difficult because people tend to commit themselves to habits that have evolved over long time spans. This problem may be confounded by fear of change and risk. An example of this occurs in the resistance to technological innovations. Heat pumps used for conditioning buildings have lower capital costs than comparable HVAC systems. In addition, they are cheaper to run. Even so, however, these devices are not the first choice of many building designers.

Low Literacy Rates

It was estimated in Canada in 1991 that 16% of Canadian adults were functionally illiterate in either official language, and 14% were innumerate[151]. If an individual cannot recognise numbers in isolation or cannot read, that individual will not be able to understand non-verbal information related to energy efficiency.

Intermediaries and Split Incentives

The presence of intermediaries such as landlords or building contractors may have an effect on the success of efficiency programs. These individuals are often responsible for the initial design and purchase of building components, but are not responsible for the operating costs. Therefore, energy efficiency may not be an important factor in the decision-making process of these individuals, who choose options based on the least expensive capital cost rather than the lowest lifecycle cost or environmental impact.

There is also the issue of "split incentives" where individuals who use energy in residential buildings may be different than the individuals who pay the energy bills or who own the energy using devices. This is often the case in multi-family residential buildings where landlords have little incentive to improve energy efficiency because the energy costs are passed on to the tenants, or where tenants have little incentive to reduce energy consumption because the utility charges are included in the rent.

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[150] Stern, P.C., Aronson, E., Energy Use: The Human Dimension, New York, W.H. Freeman, 1984.
[151] Statistics Canada, Catalogue Number 89-525E, Adult Literacy in Canada: Results of a National Survey, Ottawa, 1991.

Unavailability of Product or Service

If there is little demand for energy efficient products, suppliers may not maintain energy efficient equipment in stock for when it is required by customers. Customers may have to spend extra time and effort locating distributors of energy efficient equipment or design, installation, or maintenance services.

Lack of Financing Options

Loans for energy efficiency retrofits to existing housing may be difficult to secure because they do not fit into the traditional structure of financial sector operations.

5.3 POTENTIAL POLICY AND PROGRAM OPTIONS

This section reviews the potential for new and emerging policies and program measures for enhancing the adoption of GHG reduction opportunities discussed in Chapter 3. Specific policy and program option within the following categories are considered:

- Dissemination of Information
- Regulations, Standards, and Codes
- Financial Mechanisms
- Utility Sponsored Measures
- Government Operations
- Macro Economic Level Measures

The principal advantages and disadvantages of each category are discussed, and then specific policy and program options that have studied or proposed are presented.

5.3.1 Dissemination of Information

Information programs can help in achieving energy efficiency and GHG emission reduction improvements by providing consumers with the technical and economic information they need to make informed decisions. However, information programs are limited in their ability to affect change, as information is easily forgotten, and individual consumption patterns are difficult to alter without stronger motivational methods. Many conservation programs rely on the process of diffusion of information for improving efficiency levels. There are a number of limitations and drawbacks to this process. Information programs if not properly designed can act as barriers to achieving improvements as previously discussed. The process is also slow, and it is difficult to control and predict where or how much effect the programs will have. Finally, the whole process relies on an individual's willingness to participate. The low rates of success that are typical of many conservation programs suggest that a more aggressive approach to GHG emissions is required. In a similar fashion, while education programs are important, if the individuals who are being educated are not in a position to make decisions regarding consumption patterns (such as school children), the value of the programs must be questioned.

While the Public Education and Outreach Table is responsible for GHG emission reduction information transfer, a few options for information programs specific to the residential sector include:

Training For Municipal Building Inspectors

Training programs for Municipal Building Inspectors could be implemented to improve inspectors' understanding of energy efficient and GHG reducing building construction practices. Improved training would allow building inspectors to inhibit poor energy construction practices and pass on their knowledge to builders.

Training for Building Supply Retailers

Building supply retailers can be key players in energy efficient construction due to the products that they stock and the information on equipment, materials, and construction practices that they pass on to their customers. Training programs for retailers that focus on best available equipment, materials and practices could be valuable for promoting desirable technologies and getting key information to consumers.

Training programs targeted at appliance retailers could also be used to help encourage purchases of energy efficient appliances.

Education of Consumers to Demand Certified Renovation Contractors
With a process in place for certifying building renovation contractors (with training in energy efficiency), information programs could encourage homeowners to use only certified renovators.

Building Occupant Information Programs
Information programs targeted at building occupants can be used to educate occupants on the impact of their behaviour on energy consumption and resulting GHG emissions. Information programs could show occupants how they could change their behaviour to reduce consumption and what impact these changes would have on climate change, thereby providing a much more direct link between energy consumption and environmental impacts than previous energy efficiency information programs.

Similar information programs can be used that target *Building Managers.*

5.3.2 Home Energy Rating Systems

Performance monitoring and labelling can potentially be an important market-based driver for increased energy retrofit activity and sales of energy efficient buildings, and may prove to be the most valuable approach for linking together a number of potentially effective GHG reduction policy and program opportunities.

Energy performance labelling of new buildings can create a marketing opportunity for builders whereby they can use the rating to create a marketing advantage over the competition through improved building energy efficiency, comfort, health, safety, and/or durability.

Energy performance labelling of existing buildings can be used to market energy retrofits by providing an effective communication tool for conveying the benefits of retrofit options. A good example of this is the opportunity afforded to existing home renovation contractors of using the *EnerGuide For Houses* energy rating system. Developed by NRCan, this program involves piggybacking energy retrofits onto their existing everyday home renovation activities. The program is more than simply a rating system, however; it also educates the customer by identifying how their house is performing in different areas and what could be done to improve performance. Contractors can use the information provided from the rating system as a sales tool to sell homeowners improvements in home comfort, health, and safety. They can also add other products to the rating system that describe exactly what products, installation methods, and associated costs can be used to improve comfort, health and safety, and what benefits are associated with each option. For example, contractors can show the homeowner how comfort can be improved through window upgrades (more energy efficient windows) thereby reducing window condensation or reducing cold window surfaces. An another example is demonstrating how to reduce health risks associated with carbon monoxide leakage by installing direct vented (more energy efficient) furnaces and other combustion appliances.

The energy rating is more successful if used as a surrogate for comfort because it is easier to sell comfort, health, and safety than energy efficiency. The capability of providing instantaneous energy retrofit benefit information specific to the customers home in a sales environment greatly enhances the chances of marketing success. The federal government is currently providing a subsidy to this program to increase its rate of implementation by paying delivery agents to perform EnerGuide for Houses ratings.

Another key opportunity for energy performance rating systems is the potential to link with, and enable the success of, other GHG reduction opportunities. A government-accepted energy performance rating system is essential for the success of a GHG emissions permit or credit trading program. Building owners would require an emissions rating before and after retrofit in order to verify emission reductions so that they could sell their credits. Performance rating upon the sale of all new and used buildings would provide a benchmark for the new purchaser who would only then require a rating upon completion of retrofit to be able to sell their credits.

Performance rating systems would also enhance the opportunity for other GHG reduction options by providing a common, accepted rating methodology. Some of these other options include:

- reduced interest rates for energy efficient new home mortgages
- reduced interest rates for energy retrofit loans
- Tax reductions (property, income tax, accelerated capital cost allowance etc.) for energy efficient or GHG reducing buildings.

Policy and program options for additional performance labelling include:

Continued and Increased Support for Existing EnerGuide for Houses Rating Program

Continued funding for home renovators to use the EnerGuide for Homes rating system, with the number of houses available for rating subsidies increasing over time as the program becomes more successful.

Development of a Multi- unit Residential Building EnerGuide Rating System

A rating system similar to the EnerGuide for Houses rating program could be developed for multi-unit residential buildings. The rating system could focus on the benefits of energy retrofits that are of particular interest to different owner types such as durability and cost issues for rental building owners, comfort, health and safety for condominium owners. The cost of performing energy ratings could be subsidised to enhance implementation similar to the program for houses.

Energy Rating Mandatory for New Houses
All builders could be required to perform EnerGuide ratings on new houses and multi-unit residential buildings and to make the rating information available to consumers.

Energy Rating Upon Resale
Home purchasers or sellers could be encouraged to perform an energy rating upon sale. Although it would be difficult to make such a requirement mandatory, lending institutions, home inspectors, or other resale stakeholders could encourage it. One potential barrier could be presented by real estate agents, since a low rating could reduce the marketability of the home.

Acceptance of EnerGuide as a Standard for Emissions Trading
The federal government could establish the EnerGuide rating system as an accredited method of accounting for GHG trading credits, encouraging building owners to start obtaining credits and the large GHG emission industries that would be large purchasers of credits to start enticing credit sellers. In its present form the Energuide rating does not calculate emissions, and would therefore have to be modified to be useful as a standard for emissions trading.

5.3.3 Regulations, Standards, and Codes

The use of regulations, standards, and building codes is widely discussed in the literature, and there are a number of issues surrounding these choices of policy instrument.

It is first important to understand that building and equipment standards and codes by themselves do not necessarily require a mandatory compliance by builders or manufacturers and other affected players in the economy. Typically developed through extensive consultations, these standards are complied with on a voluntary basis until a regulatory authority is established and/or applied, at which point they become regulations. In other words, a legislatively-based enforceable set of regulations must be adopted under which specific technical standards and codes are referenced for compliance.

Standards and regulations have been effective in reducing the energy consumption of new buildings in many countries[152]. If appropriately set and updated, they can ensure a continual improvement in energy efficiency over the long term. Regulations are usually considered a "second best" policy choice, however, because they can be relatively inefficient. While this may be true when the options of taxes or tradable permits exist, given the diversity of actors in the residential sector regulations appear to have a number of advantages. For example, it may cost BC Hydro in the order of one million dollars to provide an incentive program and to market that program effectively. Conversely, the Ministry of Energy, Mines and Petroleum Resources in BC was able to implement an energy efficiency regulation for appliances at a cost of approximately fifty thousand dollars[153]. Regulations are also an efficient means of overcoming the barrier associated with intermediaries. If those intermediaries do not have the choice to purchase inefficient devices, there is no longer a problem for the individual who must pay the operating costs. Because regulations are capable of transforming entire markets, they are a potentially powerful policy instrument.

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[152] Organization for Economic Cooperation and Development (OEDC), Energy Efficiency and the Environment, OECD, Paris, 1991.

However, standards and regulations have a number of drawbacks. They tend to be a relatively inflexible policy tool. (Although it is not certain how much flexibility is optimal, nor is it clear whether the reduction in uncertainty derived from standards offsets the disadvantage of lack of flexibility.) A second argument against regulations is that they may act as a ceiling as well as a floor since there is no incentive to surpass the requirements of a standard or regulation. They can generally eliminate only the poorest practices, not promote the search for the best practices possible. To ensure continual improvement they must be updated.

A final criticism of regulations has been expressed by Conover et al[154] who assert that the effort needed to enforce a regulation is correlated to the complexity and stringency of the standard. This points out the need to complement the introduction of a new standard with such support as education and direct training in order to increase the market penetration of the new technologies and practices, before the standard is adopted as regulation. With widespread use of the standard before regulation, enforcement becomes much easier.

Further, while codes -- be they prescriptive or objective based --may substantially influence new construction, they typically have little influence on existing buildings--namely those which are going to dominate emissions from the building sector for many decades.

A number of options exist for new standards and regulations in the residential sector as described below:

Equipment Regulations

Both the federal government and most provinces regulate the energy efficiency of new residential appliances and equipment. Both levels of government try to work in concert with one another.

Under the Federal Energy Efficiency Act, twenty-one types of energy consuming residential products imported into Canada or shipped between provinces must currently meet minimum levels of energy efficiency. Products currently regulated federally (effective dates during 1995 and 1996) include certain types of space heating and cooling equipment, domestic hot water heating equipment, lighting, household appliances, and electric motors. The fourth amendment of the Energy Efficiency Act is dated for implementation on December 31, 1998 and includes twelve types of products with updated or new standards. A summary of existing and proposed updates to federal equipment standards is shown in Appendix B.

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[153] Barry, M., Ministry of Employment and Investment, Personal Communication, Victoria, B.C.,

[154] Conover, R., Jarnagin, R.E., Shankle, D., Commercial Building Energy Standards Implementation: Myth vs Reality, Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, pp. 6.27-6.34, 1994.

The proximity of Canada to the US and the integration of the manufacturing industry is currently limiting the rate of implementation and stringency of Canadian Federal regulations. We are generally making changes in conjunction with those made in the United States. Dumping of non-compliant equipment into the Canadian market following increases in stringency of US regulations can also be an issue that can increase the need for updating our own regulations.

Jurisdictional issues within Canada can be a problem in regulating residential products. While federal regulations are effective for equipment and appliances that cross provincial or federal borders, they are less so for products manufactured and sold within one province (which is common in the case of windows and doors).

Options for new equipment regulations and increased stringency of existing regulations include:

Condensing Gas Furnaces

The federal government is looking into a future condensing gas furnace standard. The US will probably not implement such a high standard because the country is less space heating dominated than Canada. As a result, this is one key area where Canada will probably have to take the lead over the US.[155]

Windows

NRCan is presently looking into the possibility of regulating minimum standards for windows. The main problem with window standards, however, is that windows are often manufactured and sold within the same province. Since they do not cross provincial or federal boundaries they are not subject to federal regulations. Each province would have to set and enforce its own regulations. One standard could be developed that applies across the country but has regionally appropriate rating or performance levels.

Gas Fireplaces

A test standard for gas fireplaces is in the approval stage and the federal government is looking at implementing a standard in the future.

Refrigerators

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[155] Conversation with John Cockburn, Natural Resources Canada, September, 1998.

The US has set a date of July 2001 for implementing a new refrigerator standard that is approximately a 25% improvement from the current Canadian-regulated level. The federal government is planning on regulating the same standard soon after this date.

Incandescent Reflector Lamps, Water Heating Equipment, Fluorescent Lamp Ballasts

The federal government is planning increases in stringency in the future.

Water Heating Equipment, Clothes Washers, Transformers, Fluorescent Lamp Ballasts

These are the major areas of priority for US activity in creating new regulations and more stringent standards are expected to be implemented in the early 2000's.

Building Codes and Standards

Model building codes and standards developed at the federal level do not require mandatory compliance until adopted in whole or in a modified version by a regulatory authority (provincial, municipal, or regional government), at which point they become enforceable regulations. The National Building Code has been adopted, and provides the basis of most provincial and local building regulations.

The Model National Energy Code for Houses (MNECH) and the Model National Energy Code for Buildings (MNECB) have been created to provide a common structure for energy efficiency regulations for buildings across the country. The MNECB applies to commercial buildings and includes large multiunit residential buildings. As of the time of writing of this report, neither of these model codes has been widely adopted. They have, however, influenced building codes in some jurisdictions. The Model National Energy Code for Houses has not been adopted by a single jurisdiction. The Province of Manitoba has, however, included some of its prescriptive requirements, and an option for using its performance method in their provincial building code. The MNECB has been referenced in the Ontario building code so that buildings have to comply either with it or ASHRAE 90.1. No other province or territory has referenced the MNECB in the provincial building code, however the Federal Government, and the provincial governments of British Columbia and Alberta, have voluntarily adopted the MNECB for their own buildings.

There is opposition among the home construction industry and municipal governments to increased regulation of buildings that would occur as a result of implementation of energy efficiency regulations (such as implementation of the MNECH), because of opposition to increased regulatory burden and construction costs. What is not widely recognised, however, is that minimum energy efficiency standards for buildings are already included in most building codes, and have been so for a long time. The provinces of BC, Alberta, Manitoba, Ontario, and Quebec already have minimum energy efficiency regulations for new homes, either through their building codes or a separate regulation (Quebec only). During 1996, single-family starts in these five provinces represented 89%

of new housing activity in Canada. The Province of Manitoba as an example has included minimum energy efficiency regulations for new houses since 1976.

There is much less opposition in the commercial building construction industry to adoption of the MNECB.

The MNECH and MNECB standards do not promote radical energy efficiency improvements over current new building practice. These standards, like all other codes, are minimum standards that do not necessarily represent optimised energy efficiency levels that account for societal benefits of GHG reduction. They are based on cost-effective levels of energy efficiency based on regional energy prices. However, implementation of these standards would provide some improvement, and eliminate the worst practices. They would also provide a level of consistency nationally, eliminating the significant variance in current provincial energy efficiency regulations.

New voluntary standards (such as the existing R2000 Standard) that go significantly further in reducing energy consumption and GHG emissions can also bring new technologies and practices into the market. If supported with education and direct training to increase their market penetration, they can set the stage for more stringent building code regulations to eliminate the worst practices.

Options for encouraging regulation of existing building codes and development of new standards for reducing GHG emissions include:

Encouraging Adoption of the Model Energy Codes
The federal government could encourage the adoption of the MNECH and MNECB by provinces and local jurisdictions.

Integration of MNECH and MNECB Prescriptive Standards into Existing Building Codes
Instead of implementing the Model National Energy Code for Houses as a separate set of regulations, provinces could be encouraged to follow the lead of the Province of Manitoba, and incorporate the MNECH requirements into existing building codes. This method would significantly reduce opposition to new regulations. A similar approach could be taken for the MNECB.

MNECH Modified to Minimise GHG Emissions
The MNECH could be updated to make it based on GHG emission reduction, rather than energy reduction. Rather than developing requirements based on the cost effectiveness of energy reduction, they could be based on cost effective GHG emission reduction measures with environmental externalities (CO2 emission costs) taken into account. Environmental externalities could be internalized by adding an environmental credit or by reducing the discount rate to zero when defining the cost effectiveness of measures. The Province of Manitoba used an environmental multiplier to take into account environmental externalities when evaluating the cost

effectiveness of MNECH energy efficiency measures in their new provincial building code.

More Frequent Upgrading of Model Energy Codes

The MNECH and MNECB standards could be updated more frequently than the current five year cycle to take advantage of changes in energy prices and new technologies.

New R2000 or Advanced House Type Standards

As mentioned previously, the existing R2000 standard has been limited in direct market penetration but extremely effective in bringing new technology and construction practices into the market. New standards that go further than the present standards could be developed to bring the next level of new technology and construction practices into the market. The standard could be regionally-focused in its GHG emission reduction technologies and could bring into the mainstream market the next level of new and existing cost effective technologies, taking into account external GHG emission costs. The next standard could be either a small step forward from present voluntary standards, or a large leap, with advantages and disadvantages to each approach.

MNECH for House Retrofits

The MNECH could be adapted to develop a model code or voluntary standard for energy efficiency retrofits to the existing housing stock. Work has already been initiated by NRCan to assess the potential for adapting the MNECH to the existing residential building stock, and for developing energy efficiency retrofit guidelines for houses.[156].

Increased Enforcement of Existing Building Codes and Standards

Government operations could allocate greater resources to existing building code and equipment standards to ensure greater compliance. For example, the Vancouver Energy Code, which is based on the ASHRAE 90.1 Standard, applies to new construction of multi unit residential buildings in Vancouver but is currently not strongly enforced. Design to this standard results in average annual energy reductions of 9% to 21%[157] in high and low rise multi-unit residential buildings in Vancouver.

Certification of Renovation Contractors

A national certification program could be introduced for certifying home renovation contractors that have been educated in the sales tools, equipment, and installation methods of energy efficient building renovations.

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[156] Anil Parekh, Personal Communication, Natural Resources Canada, 1998.

[157] BC Hydro, ERG, High and Low Rise Apartment Building Audit and Simulation Study, October 1994

5.3.4 Financial Mechanisms

Energy Pricing

The role of economic rates (through price and price structure) is frequently seen as the most important way to encourage consumers to conserve energy and reduce GHG emissions[158]. However, current pricing frequently does not reflect this view, as the price for energy is usually less than the cost of providing additional supplies. Based on information from the (now defunct) BC Ministry of Energy, Mines and Petroleum Resources[159], the price for natural gas is approximately 2.5% less than its long-run marginal cost. Similarly, the price of electricity is approximately 12% less than its long run marginal cost. Providing consumers with inaccurate price signals for energy may lead to misallocation of resources, resulting in excessive energy consumption and GHG emissions above the economically efficient level. Admittedly, however, the current information relates only to British Columbia in the mid-1990's and further research is required to estimate the divergence between price and long run marginal cost for other regions in Canada.

In making the argument for price change as a method of reducing energy consumption and GHG emissions, the price elasticity of demand provides useful information. The price elasticity of demand measures the percentage change in demand resulting from a 1% change in the price of a commodity. In a recent rate design application, B.C. Hydro used an aggregate coefficient for British Columbia of -0.67[160]. Similarly, the price elasticity for natural gas is estimated by B.C. Gas to be in the range of -0.046 to -0.013[161].

The magnitudes of price elasticity for electricity and natural gas are significantly less than unity. This implies that a change to the price of electricity and natural gas will generate less than a proportionate decrease in energy consumption. This suggests that large price increases may be required to achieve moderate reductions in GHG emissions. Therefore, it is not clear that price increases alone provide the most appropriate mechanism for reducing GHG emissions in the residential sector. This is especially true in the short and medium time frames.

Rate Design

An alternative or supplement to uniform price increases is rate design. Referring again to work in British Columbia, the British Columbia Utilities Commission has stated that because rate design "can be effective in setting rate structures that expand public awareness by

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[158] British Columbia Ministry of Energy Mines and Petroleum Resources, British Columbia Energy Policy: New Directions for the 1990's, Victoria, B.C., 1989.

[159] British Columbia Ministry of Energy Mines and Petroleum Resources, Supply and Requirement Forecast: 1993-2015, Victoria, B.C., 1994.

[160] British Columbia Utilities Commission, In the Matter of a Rate Application by British Columbia Hydro and Power Authority, Vancouver, B.C., April, 1990.

[161] British Columbia Utilities Commission, Decision, 1994/95 Revenue Requirements Application, Phase 2, Vancouver, B.C., Aug 1994b.

sending appropriate pricing signals...rate design [is] the preferable vehicle for promoting conservation and efficient use through customer rates" [162].
It is important to assess the value of price and rate structure within the criteria framework for evaluating policy options outlined previously. The issue of efficiency is an important policy goal. The most efficient way for a commodity to be priced is through market forces. However, because the price elasticity for electricity and natural gas are significantly less than unity in the short and medium term, large price increases would be required to achieve moderate reductions in GHG emissions. In addition, due to the presence of multiple market failures for energy (including GHG emissions), it is impossible for the price to ever be defined optimally. However, on the basis of the alternatives, pricing must still be acknowledged as an important method of achieving policy goals efficiently.

An advantage of pricing and rate design over other options is the ease of implementation and simplicity of monitoring GHG reductions. In addition, policy based on pricing and rate design can transform entire markets, thereby resulting in increased diffusion rates of technology fuel switching and consumption patterns. This is in contrast to the utility-sponsored approach that diffuses into the market on a building-by-building basis.

Other advantages of innovative rate structures include: the potential for reducing the invisibility of the energy supply to customers, positively affecting individual behaviour, and encouraging the use of automated systems to schedule and shed loads. Setting pricing to reduce consumption during times of utility peak demand will do more to reduce GHG emissions than can simple energy savings because often peak demand is met on the supply side with highest carbon content forms of energy.

Utilities can use innovative rate structures to encourage customer energy efficiency and reduce demand, particularly during times of peak demand on the utility. Inverted rate structures, tiered pricing, load control rates, time of use rates, and real time pricing are a number of options, some of which have already been put in place by some utilities.

Inverted Rate Structures

This refers to declining block rates that are "inverted" so that the customer pays for the first block of energy at a low "lifeline" rate, and then pays increasingly higher rates with corresponding higher consumption.

Load Control Rates

Reduced energy rates can be offered to customers who participate in load control programs. Utilities commonly control the loads themselves through powerline or radio frequency control.

Time-of-Use Rates

Time of use rates encourage customers to shift energy consumption patterns from utility on-peak to off-peak periods. Under these rates, customers typically face higher energy and demand charges during on-peak periods.

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[162] British Columbia Utilities Commission, Annual Report, 1993, Vancouver, B.C., May 1994

Real Time Pricing

Real time pricing is the use of electricity rates that reflect current system costs. Customers are provided with a utility marginal capacity cost-based price, typically on a day-ahead basis, and the customer has the option to curtail consumption in order to obtain a reduced rate.

Rebates and Subsidies

Subsidies and rebates are possible for supporting desirable technologies, designs, systems, and so on, and can have the advantage of increasing the use of a technology and thus lowering production costs. They also help promote technologies through increased visibility and consumer awareness. They are generally a short-term rather than a long-term solution because they are usually eventually removed.

The disadvantage of rebates and subsidies is that they add further distortions in an already badly distorted market. Another argument against them is that the industry being supported does not have to become economically efficient because of inflated return. From a macro economic perspective, efforts should instead be placed on eliminating existing subsidies to the fossil fuel industry, resulting in technologies becoming economically cost effective without subsidies.

Subsidies to Existing Energy Efficient Technologies

Providing subsidies to technologies that are already economically viable can result in faster adoption rates. There are a wide number of energy efficient technologies identified in Chapter 4 that are currently economically viable and could significantly reduce GHG emissions if implemented on a larger scale. Subsidies targeted towards those technologies with the greatest technological GHG reduction potential could increase the adoption rates of the most desirable technologies.

Subsidies for Energy Efficient Low Income Housing

Subsidies, incentives or rebates for energy efficient housing could be provided to low-income housing purchasers or builders. For low-income households, seniors, persons with disabilities, and northern/remote residents, energy costs are a much greater burden than for most Canadians. They are also the populations that are the least able to afford energy efficiency improvements, and would benefit the most from new construction and retrofit energy efficiency subsidies.

EnerGuide for Houses

The EnerGuide for Houses energy rating system can be thought of as a unique subsidy program that encourages the piggybacking of energy retrofits onto the everyday activities of existing home renovation contractors. The federal government is paying delivery agents a fee (the subsidy) to perform energy ratings on existing homes. The program identifies how houses are performing, what should be done to improve performance, and can be used as a sales tool to sell homeowners improvements in home comfort, health, and safety. To improve home comfort the contractor then performs energy retrofit work. The benefit to this type of approach is that although there is a subsidy involved at the initial stage, the rest of the process is market driven.

Carbon/Energy Taxes

While the adoption of carbon taxes is not being considered by the Canadian Federal Government at this time, other countries have adopted, or are considering adopting, such an option. In most OECD countries, almost all forms of energy are taxed to varying degrees, not primarily for greenhouse gas purposes, but to raise government revenues or to internalise other externalities. In fact, there is often an almost inverse relationship between fossil energy price levels, including taxes and subsidies, and their carbon content; that is to say, fossil fuels with higher carbon content have lower end-use prices than those with lower carbon content[163]. Similar to raising the price of fuel, it appears that taxes would have to be very substantial in the short and long term, covering the entire spectrum of fossil fuels, to be effective at reducing the concentration of GHG's in the atmosphere.[164]

Five countries (Denmark, Finland, the Netherlands, Norway and Sweden) have adopted carbon/energy taxes that generally include some rebates or exemptions for industry on competitiveness grounds, or alternative measures to achieve similar objectives. At least three other countries have considered modest carbon/energy taxes (Australia, New Zealand and the US) but those proposals have not been accepted.

The European Union is in the process of considering a proposal for a common carbon/energy tax put forward by the European Commission. The principal policy objective of taxing carbon and/or energy is to provide incentives to reduce CO2 emissions, whether through fuel switching, energy conservation, or modal shifts, especially in a context of relatively low energy prices. Taxes on carbon/energy also help reduce other environmental externalities. Studies indicate that the secondary benefits achieved through reductions in other environmental impacts could offset part of the social cost of taxes. In some cases, however, countries have already taken independent steps to abate other environmental impacts, therefore reducing the significance of secondary benefits. Revenues from carbon/energy taxation can be used to reduce other taxes that are considered to introduce high distortions to the economy, and to help achieve other policy objectives.

Other Tax Options

Reduced Property, Sales, or Income Taxes

Federal, provincial, and municipal governments can stimulate the market by reducing income tax, GST, provincial sales taxes, or property taxes on energy efficient equipment and/or new homes. As a successful example, the Province of

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[163] OECD, Policies and Measures for Climate Change Mitigation, Paris, France, August 1997

[164] OECD, Energy Efficiency and the Environment, Paris, France, 1991

Manitoba reduced provincial sales taxes on energy efficient windows, and sales increased. When they eliminated the tax breaks, increased sales continued[165].

Municipalities could reduce property taxes, development charges, or permits for new homes or renovated homes that meet certain energy efficiency targets in order to encourage energy efficient new construction and renovation. Tax breaks on energy efficient construction or renovation would require an established rating system for verifying eligibility.

Accelerated Capital Cost Allowances

As an incentive to rental building owners in particular, depreciation rates could be accelerated for writing off capital costs associated with investments into energy efficient buildings and equipment or renewable energy systems.

Loans

Access to financing can be a major barrier to the purchase of energy efficient new homes or the retrofit of existing homes. However, lending institutions are starting to provide reduced mortgage rates for energy efficient new home purchases, and financing for home renovations is becoming easier with contractor/bank alliances.

Energy performance contracting by Energy Service Companies (ESCO's) has been fairly successful in the commercial sector at providing financing for energy retrofits in return for money saved in reduced energy bills. However, this type of program has not been successful in the residential sector except for with the largest multi unit residential buildings. Increased access to energy performance contracting-type financing for smaller buildings would increase energy retrofit activity in these buildings.

Financing for energy retrofits alone does not seem to have great potential in the single family residence sector. Energy retrofits can, however, be piggybacked onto other types of renovation work, whose level of activity would increase with increased access to financing.

When determining the mortgage that a new homebuyer or existing home renovator can afford, banks look at the customer's debt service ratio. Lenders use a standard PITI (principal, interest, taxes, and insurance) mortgage qualification formula to determine the allowable mortgage. Some banks are now offering Energy Efficiency Mortgages for energy efficient homes, taking into account that people are spending less on utility bills.

Because transportation costs are also a significant expenditure for most homeowners, pilot projects in the US are starting to also take location (and thus related transportation costs) into account. These types of lending programs are particularly significant for expanding homeownership opportunities for low and moderate income households and neighborhoods.

Mortgages for Energy Efficient New Homes

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[165] Conversation with Ken Klassen, Manitoba Ministry of Energy and Mines.

Some financial institutions are already providing mortgages and loans at lower interest rates for energy efficient new homes and retrofits. The Bank of Montreal offers a 0.25% rate reduction and Canada Trust offers a 2% cash bonus on the principal for certified R-2000 homes.

Location Efficient Mortgages (LEM's)

In looking to future initiatives in private energy efficiency financing, one approach that is rapidly gaining attention in the U.S. is the "Location Efficient Mortgage" (LEM). The LEM is based on the planning and development concept of "location efficiency" which recognises and quantifies the energy efficiency and environmental benefits of locating households to reduce transportation energy use, thereby reducing household operating costs. Households located in rural and suburban areas spend proportionally more of their household income on transportation than do urban dwellers. They also represent greater contributors of transportation-related GHG emissions. Location efficient mortgages recognize this fact in calculating total debt ratios and allow customers who live closer to mass transit to qualify for larger mortgages, giving low and moderate income families more choices by enabling them to live in more desirable neighborhoods. Housing located closer to mass transit is typically more expensive, so LEMs can help increase the accessibility of living in these areas by leveling the playing field. The US federal government is supporting the introduction of LEM's with a commitment of $100 million from the Federal National Mortgage Association (Fannie Mae) to pilot the program in three large US cities.[166] The LEM offers the promise of making the altogether critical linkage between addressing energy and GHG emission reduction opportunities in housing and transportation.

Utility Supported Energy Retrofit Financing Programs

Utilities have a vested interest in financing and performing energy retrofits. As the industry deregulates, individual utilities are looking for ways of keeping existing customers and providing new services. By financing energy retrofits (directly for larger buildings or through home renovation programs for houses) they can increase their sales of energy services, maintain customer loyalty, and generate income from the financing programs.

One interesting model that is being piloted in the Unites States includes the Federal National Mortgage Association (Fannie Mae), which is working with utilities to provide capital for energy efficiency improvements at the time of major retrofits. By working with utilities and retrofit contractors to originate and service loans in conjunction with other wrap around services, Fannie Mae has positioned itself to become the largest financier of energy efficiency in America[167].

Small Business Loans Act Program

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[166] Materials provided by Ken Klassen, Man. Dept. Energy and Mines and also, from internet site: www.cnt.org/lem/apa.htm

[167] Reference http://solstice.crest.org/efficiency/irt/eenv.htm

The small business loans act program is a partnership between government and private lending institutions that enables the two entities to share risk inherent in extending credit to small businesses. Loans from this program could be used to provide energy retrofit loans to multi-unit residential facilities, condominiums, nursing homes, social housing, and co-op housing projects. Marbek is currently carrying out a study looking into the potential of this program for Environment Canada.

5.3.5 Tradable Emission Reduction Permits

An emissions trading strategy, with the creation of a new commodity with real current and future market values, enables previously external environmental considerations to jump to centre stage in corporate and other economically-based decision-making. A combination of mandatory and voluntary market drivers can be mobilised to support an accelerated rate of investment in energy efficiency.

In an emission reduction credit (ERC)-based open market system, government, in consultation with industry, would establish baselines for existing and new buildings that reflect current average energy and emissions performance. These baselines would appear to be very similar to existing performance-based building standards or codes. The key difference would be that the baseline would not describe a minimum performance standard for new construction purposes. Any time an existing building were retrofitted or a new building constructed to perform "better-than-baseline", the developer or owner would have created bankable, tradable ERCs. In the early stages of a national emissions trading regime, the most likely market for these ERCs would be major emitters that have accepted GHG caps or reduction schedules through voluntary covenant or regulation. ERCs could also be traded within the real estate market, much the same as unused "airspace" or undeveloped floor space ratio is currently traded in that marketplace. As the overall energy and environmental performance of the building stock improves, the baselines from which ERCs can be created can be adjusted, in much the same manner as standards and codes are revised in today's normal practice.

This whole discussion presumes that there is, or will be, a market for ERCs. At this time, a small but real market for ERCs exists. Buyers represent very large emitters that can justify investing in measurable, verifiable emissions reductions as a hedge against the risk of future regulation.

With the creation of an ERC market, performance contractors and energy service providers — firms and individuals that typically retrofit existing buildings on the basis that their services will be paid for by resulting operating cost savings — would see their margins expand, leading to better market penetration of those services. With baselines for new construction in place, a commercial activity that parallels performance contracting would arise, but with a view to financing the incremental soft costs of bettering performance of new buildings at the time of construction. If emission reductions have a market value, then incorporating building simulation in the design phase could become cost-effective and common practice. The result would be accelerated learning and innovation in new construction. Developers of buildings with superior energy and emissions performance would enjoy a competitive advantage over others, should they choose to package and sell ERCs, or employ them as a source of financing. There would be market demand for building performance monitoring and reporting, which, in turn, would lead to increased innovation. The end-users of buildings might or might not start consider paying a premium for highly efficient, environmentally superior real estate square footage. But with the emergence of a vibrant secondary market for ERCs, developers and/or building owners would be able to derive a financial return on their investment in superior performance, even without end-use market support.

5.3.6 Utility Sponsored Measures

There exist many programs offered by utilities under the framework of Integrated Resource Planning (IRP) and Demand Side Management (DSM). There are a number of points to emphasise in order to assess the value of DSM and IRP as a policy option for GHG emissions reductions. First, it is difficult to predict or evaluate the effectiveness of these programs. Because participation is voluntary, it may be difficult to design a program with enough flexibility to attract a large number of participants. Participation rate is a critical factor affecting the success of utility-sponsored DSM programs. As the review by Berry[168] suggests, participation is frequently of the order of 6%.

A second issue of DSM programs is their cost. In the case of B.C. Hydro, the financial incentives are seen as a temporary measure to promote and publicise conservation to customers. The high cost of some DSM programs makes them a less attractive long-term component of conservation strategy.

A third concern of utility-sponsored conservation programs is the allocation of risk and the "principal agent problem". As noted by Sutherland[169] and Nadel et al[170], the utilities (the agent) both make DSM investment decisions and are in the position to profit from the gains of successful investments. However, the customers (the principals) incur the risks and losses if the DSM investment is not successful.

Although there are uncertainties associated with the adoption of utility-sponsored DSM programs, incentives, rebates and grants are a positive way of introducing the concept of efficiency and conservation to consumers. As opposed to standards or price increases, the ability to evoke a positive response towards conservation is potentially a strong attribute of these programs.

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[168] Berry, L., A Review of the Market Penetration of U.S. Residential and Commercial Demand Side Management Programmes, Energy Policy, Jan, 1993.

[169] Sutherland, R.J., Energy Efficiency or the Efficient Use of Resources?", Energy Sources, Vol. 16, pp. 257-268, 1994.

[170] Nadel, S.M., Reid, M.W., Wolcott, D.R., Ed., Regulatory Incentives for Demand Side Management, American Council for an Energy Efficient Economy, Washington, D.C., 1992.

A final concern of DSM and IRP is that they often focus on energy efficiency, rather than GHG reduction. **As such, it is possible that a number of the programs could actually increase GHG emissions in the residential sector.**

Utility sponsored policy and program options include:

Energy Pricing Rate Design
(Discussed previously under Financial Mechanism)

Energy Retrofit Financing Programs
(Discussed previously under Financial Mechanism)

Green Energy
Green energy billing programs are beginning in Canada and already exist with a large number of utilities in the US. Customers generally pay a slightly higher rate for electricity that is generated from renewable energy sources, with large hydro usually excluded due to its high environmental impact. It is an effective way of providing a market advantage to cleaner energy suppliers.

The Energy Co-ordinating Agency of Philadelphia and the Pennsylvania Campaign for Clean Affordable Energy conducted a survey of electricity customers in Pennsylvania, and found that 68% of all customers, regardless of their income, would be willing to pay extra for clean energy, and 78% feel it is important for their supplier to generate renewable energy.[171]

Performance Based Hook-up Fees
An alternative to traditional DSM programs is performance based hook-up fees[172]. These link building performance to the charge levied by utilities for initial connection to the grid, and would allow for reduced hook-up fees for energy efficient buildings. The attraction of this option is that such a program would encourage builders and designers to consider the long-term energy implications of their buildings. Another option is providing the utility with the authority to enforce building standards related to energy efficiency. Criticism of the performance-based hook-up fee has centred around the notion that there is no standard method of measuring the operating performance of a building. However, the development of a uniform EnerGuide for Houses type rating program may provide a solution to the criticism.

Enhanced Communications
It appears that the most rapid diversification of utility service offerings is in the area of enhanced communications. These service offerings are based on the premise that customers have a growing need for more information at a more rapid

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[171] Green Energy News Inc., Energies, 6/20/1998 vol.3 no.11.

[172] Wirtshafter, R.M., Energy Performance-Based Hookup Fees for Buildings, Energy Sources, Vol. 16, pp.483-501, 1994.

pace (e.g. real time). Such information needs may link to electric power; for example, real time prices correspond to an ever-increasing array of price options, or may link to other utilities such as telephone service. These service offerings have led to collaborations among different types of utilities, software developers and hardware providers. Some examples of potential enhanced services, directed primarily to the low-rise residential sector, include:

- Utility changes price hourly and transmits changes to customer via telephone and RTF with thermostat as interface. Appliances are programmed only to operate at certain price levels.
- Homes are connected to broadband system where lighting, security and set-back are controlled.
- PCs are used as an interface for enhanced services using telephone lines/internet, and PLC.

5.3.7 Government Operations

Federal, provincial, municipal, and other local governments can influence GHG emission reduction through improvements their own residential building operations. A few options include:

Piggybacking Energy Retrofits on Multifamily Upgrades

The existing government-owned assisted housing stock, while generally better maintained than the private rental stock, is aging, is not very energy efficient, and is in need of renewal. Federal and provincial governments should be encouraged to undertake energy retrofits while ongoing maintenance, upgrades, and renewal work is being carried out.

Infrastructure Renewal Program to Retrofit MURBs

Existing government infrastructure renewal money could be used to help the renewal of the government-assisted housing stock. Energy upgrades could be piggy-backed onto these renewal projects. Possibly, infrastructure renewal money could also be used to help with energy retrofits of private social and rental housing stock.

5.3.8 Macro Economic Level Measures

While analysis of GHG emissions within the residential sector is vital for developing public policy options, analysis at the macro level may provide insight into the impact of GHG emissions reductions within the residential sector on the larger economy (and vice versa). A World Bank study[173] notes that changes in macroeconomic policy can have a larger impact on GHG emissions than any explicit mitigation option at the project level. For example, the report cites an analysis which estimates that the removal of fossil fuel subsidies would reduce climate change emissions by 7% globally, and as much as 20% in some countries. Another study completed for the United States[174] concludes that the removal of all energy subsidies, including subsidies to non-carbon energy sources, would cause energy consumption to drop by 4% annually over the period of 1990 to 2050, as compared to the base case. The study further concludes that GNP will improve by 0.2% over the base case.

One policy option is the use of deregulation and competitive markets to determine the optimal level of energy efficiency and GHG emissions. This option is increasingly being utilised by default as we see deregulation of electricity and natural gas markets across North America, and the emergence of ESCOs to provide energy efficiency services to customers. However, due to the multiple market failures arising from energy monopolies, environmental externalities, and imperfect information, the exact role of competitive markets is difficult to define. Further, the residential sector is frequently seen as the toughest sector in which to leverage energy efficiency, due mainly to the high transaction costs.

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[173] Larson, B., World Fossil Fuel Subsidies and Global Carbon Emissions in a Model with Interfuel Substitution, Report No WPS 1256, The World Bank, Washington, D.C.
[174] Shelby et Al, The Climate Change Implications of Eliminating US Energy Subsidies. Paper presented at the Evaluating Energy Subsidies conference by the US EPA, Sept 6-7, 1995, Washington DC.

Revenue recycling is another critical issue of the impact of policy on the economy at the macro level. One study completed for the UK[175] concluded that economic gains are possible if government used the revenues from a carbon tax to decrease the amount of other distortionary taxes in the economy. Options cited include deficit reduction, or reducing taxes on non-energy products[176].

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[175] Barker et Al. A UK Carbon/Energy Tax: The Macroeconomic Effects", Energy Policy, Vol 22, No. 7, Pg 541, 1994.

[176] The World Bank, Guidelines for Climate Change Overlays, Paper No 047, Pg 136, Washington, DC, February 1997

5.4 INFORMATION GAPS AND AREAS FOR FURTHER RESEARCH

More research and policy analysis is needed in order to develop an action plan for GHG emissions reduction in the residential sector. Key areas that require further research include:

1. Modelling of the achievable potential of various groups of measures using a model that combines top down and bottom up approaches. As an example, the Markal-Macro model, which can model the following interactions, can be used:
    - The trade-off between energy expenditures and investment
    - The dynamic impacts of different levels of capital accumulation over time
    - Inter fuel substitution
    - Substitution between labour and capital
    - Autonomous conservation
    - Consumer rationality and the trade-off between consumption and investment
    - Rates of market penetration for different technologies
    - Time lags of demand in response to changing prices

2. Modelling of the effect of the integration of environmental and economic benefits and costs into an analysis of GHG emission reductions. Due to the nature of such an analysis, it is likely that the entire Canadian economy would need to be modelled using a general equilibrium model that covers all sectors of the economy.

3. Investigation of the policy options that support community based approaches.

4. The effectiveness of tradable permits as an alternative to more traditional policy approaches.

5. National strategies that arise from subsequent work needs to include provisions for regional adaptations in order to minimize the issue of leakage. In particular GHG emissions credits for a unit of electricity saved in Alberta and Quebec, for example, should be attributed different value due to the different primary energy mix.

6. The feasibility of development of an explicit national energy policy for Canada and the implications of such a policy on the residential sector.

7. Prepare a series of plausible scenarios describing (in story-like fashion) how a "portfolio" of policy options might work well together to achieve a substantial, specified reduction in GHG emissions from the residential sector.

8. Prepare a series of education campaign strategies that might contribute to creating a broad public attitude supporting changes in behaviour and regulations necessary to achieve the Kyoto commitments.

9. Review legislation in other jurisdictions to identify opportunities for co-ordinating Canada's approach to residential GHG emissions with approaches adopted elsewhere, where such co-ordination might improve effectiveness, reduce costs and avoid leakage.

10. Investigate how a complete package of residential policies might be adopted and applied by a municipality, in ways that contribute to GHG reductions. This could include sustainable development guidelines for new and renovated buildings.

11. Prepare model benefit/cost case studies for including distributed alternative energy supply systems as part of new residential developments. (Include any good examples from outside of Canada.)

12. Investigate how Canada might contribute to the development and implementation of a green building performance curriculum that could be offered to practising professionals, and integrated into educational institutions with design, engineering and planning schools.

13. Use LCA and the Foundation Paper accounting process as a framework for investigating how policy can be developed that would ensure much better feedback to all the actors in the residential sector on an ongoing basis regarding their performance in helping meet the Kyoto commitments.

14. Review all the higher priority policy options for the residential sector with a view to explicitly identifying and quantifying the extent to which the policy increases the likelihood of Canada achieving goals in other areas of the environment, and in the spheres of society and the economy.

15. Respond to the questions and concerns raised by the Buildings Table after the Foundation Paper has been thoroughly reviewed. Make corrections, clarify, fill in the gaps, and prepare an improved version that is acceptable to a larger majority of the members. Also create an additional report that uses the revised Foundation Paper to logically identify and rank the best options for new policy.

16. Analyse each of the structural factors that are now influencing energy use and GHG emissions in the residential stock, and present the best options for how to use policy to influence such factors.

17. Develop a strategy for creating policy that can respond to the regional differences in primary energy in electricity used for home services.

6.0 HOW CAN THE BUILDINGS TABLE IDENTIFY THE MOST APPROPRIATE SELECTION OF POLICY OPTIONS?

The potential for policy and program options to narrow the gap between the economic and achievable potential for reducing GHG emissions in the residential sector depends on a wide variety of factors including the cost and effort required for implementation, the ability to overcome existing market and behavioural barriers, effects on key stakeholders, the flexibility to adapt over time, etc. In order to evaluate the relative effectiveness of individual options, it is necessary to apply evaluation criteria. A proposed list of criteria is presented below.

Criteria for Use in Ranking Policy and Program Options

1. **GHG emission reduction impacts** – Total potential short term and long term impact
2. **Economic efficiency** - The extent to which the measure takes advantage of market forces
3. **Transitional costs** - The time and costs incurred by stakeholders in adjusting to new policies and programs
4. **Flexibility** - Ability of measure to adapt over time and adjust to changing levels of global warming risk
5. **Jurisdictional Limitations** – Some policy instruments require participation by authorities having jurisdiction.
6. **Distributional Consequences** - Ability of measure to equitably distribute impacts among those affected (taxes are typically seen as a regressive form of policy and additional measures are required to overcome distributional inequities)
7. **Effort required to implement, monitor and enforce the policy or measure** - Generally the stricter the standards the greater enforcement required, while market driven changes don't require enforcement
8. **Co-operation from key Stakeholders** – the willingness and capability of key stakeholders to co-operate and/or support the policy.
9. **Other Benefits** - Potential for improvements society, economy and environment

These criteria can be used by the Buildings Table to help rank the potential success of different policy and program options. The policies and programs that were presented in Chapter 5 have been preliminarily evaluated using these criteria with the results presented in Table 6.1. Which building segments can be targeted with individual measures are also presented in the table.

Table 6.1 Building Segments Affected and Potential Effectiveness of Policy and Program Measures

Measure	Building Segments Most Effected.	Effectiveness Criteria								
		GHG Impacts	Economic Efficiency	Transitional Costs	Flexibility	Jurisdictional Limitations	Distributional Consequences	Minimization of risk	Effort Required	Philosophy Match
Dissemination of Information										
Training For Municipal Building Inspectors	All new	low	high	low	low	low	low	low	low	high
Training for Building Supply Retailers	All	low	high	low	low	low	low	low	low	high
Education of Consumers to Demand Certified Renovation Contractors	All Existing	low	high	low	low	low	low	low	low	high
Building Occupant Information Programs	All Rental MURB	low	high	low	low	low	low	low	low	high
Metering	All MURB	medium	high	medium	high	low	low	low	medium	high
Home Energy Rating Systems										
Continued and Increased Support for Existing EnerGuide for Houses Rating Program	Existing SFD	medium	medium	medium	high	low	low	medium	high	high
Development of a Multi- unit Residential Building EnerGuide Rating System	New and Existing MURB	medium	medium	medium	high	low	low	medium	high	high
Energy Rating Mandatory for New Houses	New SFD	medium	medium	medium	high	low	low	medium	high	high
Energy Rating Upon Resale	Existing SFD	medium	medium	medium	high	low	low	medium	high	high
Acceptance of EnerGuide as a Standard for Emissions Trading	All	medium	medium	medium	high	low	low	medium	high	high

Measure	Effectiveness Criteria									
	Building Segments Most Effected.	GHG Impacts	Economic Efficiency	Transitional Costs	Flexibility	Jurisdictional Limitations	Distributional Consequences	Minimization of risk	Effort Required	Philosophy Match
Regulations, Standards, and Codes										
Equipment Regulations										
Condensing Gas Furnaces	All Low Rise	high	medium	medium	low	low	medium	high	high	medium
Windows	All	high	medium	medium	low	low	medium	high	high	medium
Gas Fireplaces	All	high	medium	medium	low	low	medium	high	high	medium
Refrigerators	All	high	medium	medium	low	low	medium	high	high	medium
Incandescent Reflector Lamps, Water Heating Equipment, Fluorescent Lamp Ballasts	All	high	medium	medium	low	low	medium	high	high	medium
Water Heating Equipment, Clothes Washers, Transformers, Fluorescent Lamp Ballasts	All	high	medium	medium	low	low	medium	high	high	medium
Building Codes and Standards										
Encouraging Adoption of the Model Energy Codes	All New	medium	medium	medium	medium	high	medium	high	high	medium
Integration of MNECH and MNECB Prescriptive Standards into Existing Building Codes	All New	medium	medium	medium	medium	high	medium	high	high	medium
MNECH Modified to Minimise GHG Emissions	New Low rise	medium	medium	medium	medium	high	medium	high	medium	medium
New R2000 or Advanced House Type Standards	New SFD	medium	medium	medium	medium	low	medium	high	medium	medium
Performance Based Building Codes	All New	medium	medium	medium	medium	low	medium	high	medium	medium
MNECH for House Retrofits	Existing Low rise	medium	medium	high	low	high	high	high	high	medium
Increased Enforcement of Existing Building Codes and Standards	All New	medium	medium	high	low	high	low	medium	high	medium
Certification of Renovation	All existing	low	low	medium	medium	high	low	low	high	low

Measure	Effectiveness Criteria									
	Building Segments Most Effected.	GHG Impacts	Economic Efficiency	Transitional Costs	Flexibility	Jurisdictional Limitations	Distributional Consequences	Minimization of risk	Effort Required	Philosophy Match
Contractors										
Financial Mechanisms										
Energy Pricing	All	high	high	low	high	low	medium	medium	low	high
Rate Design	All	high	high	low	high	high	low	medium	low	high
Inverted Rate Structures	All	high	high	low	high	high	medium	medium	low	medium
Load Control Rates	All	high	high	low	high	high	medium	medium	medium	medium
Time-of-Use Rates	All	high	high	low	high	high	medium	medium	medium	medium
Real Time Pricing	All	high	high	low	high	high	medium	medium	medium	medium
Rebates and Subsidies										
Subsidies to Existing Energy Efficient Technologies	All	medium	medium	medium	high	medium	low	medium	medium	low
Subsidies for Energy Efficient Low Income Housing	Low income owned low rise, tenanted MURBs, Assissted Housing, First Nations Housing	medium	medium	high	medium	low	low	medium	high	low
EnerGuide for Houses	Existing SFD	low	high	low	high	low	low	low	high	high
Taxes										
Carbon/Energy Taxes	All	high	high	medium	high	low	high	high	medium	high
Reduced Property or Sales Taxes	All owners	medium	medium	low	high	medium	medium	low	medium	low
Accelerated Capital Cost Allowances	MURB Owners	low	high	low	high	low	high	low	low	medium
Loans										

Measure		Effectiveness Criteria								
	Building Segments Most Effected.	GHG Impacts	Economic Efficiency	Transitional Costs	Flexibility	Jurisdictional Limitations	Distributional Consequences	Minimization of risk	Effort Required	Philosophy Match
Mortgages for Energy Efficient New Homes	New SFD, condos	low	high	low	high	low	medium	medium	low	medium
Location Efficient Mortgages (LEM's)	All New	low	high	low	high	low	medium	medium	low	medium
Small Business Loans Act Program	All Existing	low	high	low	high	low	low	high	medium	high
Tradable Emission Reduction Permits	All	high	high	low	high	low	low	high	medium	medium
Utility Sponsored Measures										
Energy Rate Design	All	high	high	low	high	high	low	low	low	medium
Energy Retrofit Financing Programs	All Existing	medium	low	medium	high	high	low	low	medium	low
Green Energy	All	high	high	low	high	high	medium	low	low	high
Performance Based Hook-up Fees	All New	high	high	low	high	high	high	medium	low	high
Enhanced Communications	All	low	high	low	high	low	low	low	low	high
Government Operations										
Piggybacking Energy Retrofits on Multifamily Upgrades	Existing Assisted	high	high	low	high	high	low	high	low	medium
Infrastructure Renewal Program to Retrofit MURBs	Existing MURB	medium	medium	medium	high	high	low	low	medium	medium
Research, Development and Demonstration (RD&D)	All	medium	medium	medium	high	low	low	medium	medium	low
Macro Economic Level Measures	All	high	high	?	high	low	?	low	medium	high

APPENDIX A -- PROFILE OF EXISTING CANADIAN PROGRAMS

This table briefly summarises current Canadian programs that address residential energy efficiency and energy conservation. The programs are divided into the following four main types:

- General information/education
- Technical support
- Financial incentives
- Regulations/standards/codes.

In cases where a program could fit within more than one category, the apparent main focus or feature of the program was used to determine where to place it.

Within each of these main categories, programs are grouped according to their "source": federal government, provincial government, utility or other private sector entity, and NGO/non-profit organisation.

1. GENERAL INFORMATION/EDUCATION[177]

1.1 FEDERAL GOVERNMENT INITIATIVES

Name & Source	**Resid. Sectors**	***Target* Approaches/tools**	***Start year; 1996/7 expen.***
Consumer Information, Energy Efficiency Branch, NRCan	All[178]	General energy efficient practices and alternative energy ♦ Printed materials, displays, seminars, etc.	start yr: NA $1.30 million
Healthy Housing, Canada Mortgage and Housing Corporation	All	Energy and resource efficiency, occupant health and other Healthy Housing goals ♦ Printed materials, videos etc. targeted to builders, renovation professional, home-owners; demonstrations, displays, etc. ♦ Includes significant R&D component	start yr: 1990 $ N/A
EnerGuide for Houses, Energy Efficiency Branch, NRCan (in coop with CMHC)	All existing	Energy efficiency of existing houses ♦ Home energy rating and report offering specific advice on efficiency improvement options, prepared via on-site appraisal by certified EGH inspectors	start yr: 1997 $1.00 million

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[177] While not specifically noted, many education/awareness programs do include some promotion of alternative energy sources, including renewables.

[178] All = New and existing; single family and multi-unit

Reno$ense, Energy Efficiency Branch, NRCan (in coop. with CMHC and private sector)	All existing	Energy efficient renovations ◆ Printed materials, displays etc. addressing considerations and options to apply in planning and implementing renovations	start yr: 1996 $200,000 (Each $ spent by NRCan leverages ap. $10)
Renewable Energy Market Development, Renewable & Electrical Energy Division, NRCan	All	Use of renewable energy technologies ◆ Printed material, displays, workshops, etc. identifying opportunities ◆ Program also targets IC&I and agriculture	start yr: 1995 $700,000
EnerGuide Labelling Program, Energy Efficiency Branch, NRCan	All	Energy efficiency of appliances ◆ Information on comparative energy performance via printed materials, web site, labels on new products ◆ Mandated by Energy Efficiency Act; includes C/I equipment	start yr: 1978 $1 million
HVAC Rating Program, Energy Efficiency Branch, NRCan	All	Energy efficiency of residential HVAC equipment ◆ Comparative energy performance ratings information via info in promotional material; participating suppliers voluntarily promote energy-efficient equipment	start yr: 1994 $200,000
Window Energy Performance Labelling Program, Energy Effi-ciency Branch, NR Can, in coop with Can. Window & Door Manu. Assoc.	All	Energy performance of windows ◆ Voluntary, industry-led program for certification of thermal performance of windows (ER rating) ◆ NRCan information products; CWDMA web site and annual catalogue of rated windows; and product labels and point of sale information	start yr: 1994 $150,000

1.2 PROVINCIAL/TERRITORIAL GOVERNMENT INITIATIVES

Name & Source	**Resid. Sectors**	***Target*** ***Approaches/tools***	***Start year; 1996/7 expen.***
Energy Advisory Services, Nova Scotia Dept. Natural Resources, Energy Utilisation	All	Efficient residential energy use (general) ◆ Toll-free telephone line, publications, seminars, advertising of options, advice to industry groups ◆ Program includes personal road transpo.	start yr: N/A $120,000
Renewable and Alternative Energy Info Transfer, Nova Scotia Dept. Natural Resources, Energy Utilisation	All	Use of renewable and alternative energy ◆ Preliminary analysis of specific opportunities for cost-effective use ◆ Program includes IC&I and agricultural sectors	start yr: N/A $10,000

Awareness and Coordination, Agence de l'efficacité énergétique	All	Wise energy use (general) ♦ Selective public events	start yr: N/A $ N/A This is a pilot project
Energy-Efficiency Investment Recognition Program Qué Ministère des ressources naturel-les, Direc. de l'efficacité énergétique	Existing single family	Energy efficiency of existing houses ♦ Evaluation of energy efficiency in dwellings and provision of information on potential savings in energy costs to individuals and financial institutions	start yr: 1996 $150,000 Project in pilot phase (development of eval. system)
Energy Forum, Qué Ministère des ressources naturelles, Direc. de l'efficacité énergétique	All	Effective use of energy (general) ♦ Information exchanges between provincial government and consumers via conferences, meetings, displays, advisory services, etc. (including information gathering on sector energy requirements) ♦ Program includes all sectors – IC&I, transpo, agriculture	start yr: N/A $250,000
Energy Watch Centre, Qué Ministère des ressources naturelles, Direc. de l'efficacité énergétique	All	Energy efficiency/conservation (general) ♦ Centre targets professionals, managers, researchers ♦ Program includes all sectors – IC&I, transportation, agriculture	start yr: N/A $ N/A
Energy Advisory Service, Manitoba Energy and Mines, Petroleum & Energy Branch	All	Energy efficiency/conservation (general) ♦ Toll-free telephone advice, publications, displays, workshops, etc. on home improvement measures, energy-efficient appliances, building practices, etc. ♦ Program includes all sectors	start yr: 1981 $ N/A
Home Energy Savers Workshops, Manitoba Energy and Mines, Petroleum & Energy Branch	All	Energy saving measures and energy efficient appliances and products ♦ Ap. 40 workshops/year, plus printed and audiovisual material	start yr: 1985 $20,000
New Home Workshops, Manitoba Energy and Mines, Petroleum & Energy Branch	All new	Energy efficient and environmentally responsible new homes ◊ Ap. 10 workshops/year, plus printed and audiovisual material; R2000 standards and certification promoted	start yr: 1992 $20,000
1-800 Energy Conservation Line, Saskatchewan Energy & Mines, Energy Develop-ment Branch	All	Energy conservation/energy efficiency ♦ Toll free line providing "one-stop shopping" on wise energy use: general information; brochures from NRCan & other sources; some specific client consultation ♦ Program also covers personal road transportation	start yr: 1991 $ N/A

1.3 UTILITY OR OTHER PRIVATE SECTOR INITIATIVES

Name & Source	Resid. Sectors	*Target* Approaches/tools	*Start year; 1996/7 expen.*
Meter Reading Program Gaz Métropolitan, Montréal, Québec	All	Energy saving measures (general) ◆ Provision of more frequent consumption figures to clients via remote measuring, to help clients judge where they can cut energy costs ◆ Program includes IC&I sectors and agriculture	start yr: N/A $ N/A
Customer Service Program, Gaz Métropolitan, Montréal, Québec	All	New natural gas installations ◆ Customer testimonies via printed & audiovisual material re energy efficiency/ ◆ savings from new natural gas installations ◆ Program includes all IC&I and transportation sectors	start yr: N/A $ N/A
New Building Construction Program, Centra Gas Ontario Inc.	New multi-family	Energy efficiency of new residential buildings ◆ Demonstrations, displays, workshops, printed materials, etc. ◆ The goal is to identify best mechanisms to effect market transformation ◆ Program includes new C&I buildings	start yr: 1997 $150,000 Program was only slated to run for 1997
New Home Construction Program, Centra Gas Ontario Inc.	New single-family	Energy efficiency of new houses ◆ Advertising, advisory services, displays, etc. to precondition market by shaping customer expectations and creating long-term demand for energy-efficient housing ◆ Program also includes R&D and evaluations components	start yr: 1997 $50,000 Program was only slated to run for 1997
Home Equipment Replacement, Centra Gas Ontario Inc.	All	Energy efficient equipment ◆ Awareness campaign (printed materials, seminars, advertising, advisory services, labelling, etc.) to create consumer preference for renting or purchasing higher energy efficiency products; support for dealers in marketing these products ◆ Program includes loans component	start yr: 1997 $500,000 Program was only slated to run for 1997
Apartment/Commercial Water Heating Retrofits, Consumers Gas, Ontario	Existing multi-family (apartment)	Installation of hot water conservation devices ◆ Promotion of net benefits via advertising and advisory services ◆ Provision of devices at cost	start yr: 1995 $12,000

Energy Efficient Appliance Information Program, Manitoba Hydro	All	Encourages consumers to purchase more energy efficient appliances.	N/A
Energy Efficient Hot Water Tank Program, Manitoba Hydro	Single Family	Residential program offering customers the opportunity to lease, finance, or purchase one of the most energy efficient, worry-free hot water tanks available.	Fall 1996
Power Smart Promotions, Winnipeg Hydro	All	Electricity conservation; influencing manufacturers of electrical technologies and products ♦ Development of greater customer awareness to encourage conservation and drive marketplace, via advisory services, demonstrations, printed and audiovisual materials, seminars, etc. ♦ Program includes R&D and evaluations elements ♦ Program includes some manufacturing and all C&I sectors	start yr: 1991 $444,000
Hot Water Tanks Program, Winnipeg Hydro	All	Reduced electrical consumption for electric hot water tank rental customers ♦ Advertising, advisory services, printed and audio-visual materials, displays ♦ Program includes many C&I sectors	start yr: 1993 $175,000
Energy Matters, TransAlta Utilities Corporation, Alberta	All	Energy issues (general) ♦ Advisory service via toll-free line, and other information products (e.g., printed and audio-visual materials, exhibits, seminars) ♦ Program includes C&I sectors	start yr: 1994 $200,000
Energy Saving Promotion, Alberta Power Limited	All	Energy savings (general) ♦ Campaign involving advertising, printed and audio-visual material, displays, demonstrations, labelling etc. to deliver energy-saving messages and promote energy-saving products ♦ Labelling, in co-operation with retailers ♦ Program includes agriculture sector	start yr: 1996 $75,000 One year program
School Education Program, Alberta Power Limited	All existing	Awareness of energy management, safety and renewable resources ♦ Promotion to students from K to Grade 12 via printed and audio-visual materials, displays, demonstrations, seminars, etc.	start yr: 1997 $80,000 One year program
Residential Appliance Buying Guidelines/Energy Efficiency, Edmonton Power	All	Promotion of energy-efficient appliances, lighting, cooling and control systems ♦ Information for residential customers via displays, trade shows, telephone hotline, new columns, fact sheets bill inserts etc. ♦ Program includes small business C&I	start yr: N/A $65,000

Photovoltaic Demonstration House Project, Edmonton Power	All single-family	Promotion of solar-powered panels ◆ Displays and exhibits ◆ Program also involves R&D component	start yr: 1995 $ N/A
Retail Promotions – Housing Energy Equipment, Edmonton Power	All	Promotion of electricity efficiency at point of sale ◆ Point of sale displays	start yr: N/A $10,000
Power Smart New Home Program BC Hydro	All new	Energy efficient new homes (electricity) ◆ Power Smart new homes incorporate energy-rated windows, energy-efficient lighting, low-flow plumbing fixtures ◆ Promotional assistance to builders, and Power Smart certification ◆ 1/2% off premium rate offered by some financial institutions to purchasers of Power Smart new homes.	start yr: 1995 $820,000 Program slated to end in 1998
New Home Pro-gram, West Kootenay Power	All new	Energy efficient new homes ◆ Information on equipment, systems, etc., including labelling ◆ Program is pilot	start yr: 1997 Pilot slated to run for 1 year
Energy Conservation Awareness Program, Yukon Electrical Company Ltd	All	Reduced energy consumption ◆ Consumer awareness via advertising, printed and audio-visual materials, displays and audits ◆ Information on potential benefits of use of waste engine heat of a diesel plant	start yr: 1997 $80,000 Program was only slated to run for 1 year
Energy Awareness and Information, Dept of Resources, Wildlife and Ec Dev, Energy Pro-gram Br, GNWT	All	Energy awareness ◆ Energy Awareness Month consists of promotional activities including displays, utility reduction information pamphlets and factsheets, television and radio advertising, presentations, etc. ◆ All sectors targeted (including activities beyond Energy Awareness Month)	start yr: 1993 $480,000

2. *TECHNICAL SUPPORT*

2.1 *FEDERAL GOVERNMENT INITIATIVES*

Name & Source	***Resid. Sectors***	***Target Approaches/tools***	***Start year; 1996/7 expen.***
Community Energy Technologies, Energy Technology Branch, CANMET/ NRCan	All, seniors	Community technologies to connect heat sources and sinks (e.g., district heating and cooling); and energy efficient cooling Evaluation of opportunities to install systems and technical and financial support for implementation Program includes R&D and demonstration elements	start yr: 1985 $1.06 million

2.2 PROVINCIAL/TERRITORIAL GOVERNMENT INITIATIVES

Name & Source	**Resid. Sectors**	***Target* Approaches/tools**	***Start year; 1996/7 expen.***
Building Utility Assessment/Audit Programs, Dept of Resources, Wild-life and Ec Dev, Energy Program Br, GNWT	All	Energy efficient residential buildings Walk through and/or computer assisted assessments of utility consumption, and recommendations on corrective measures and devices. Program includes C&I sectors (existing)	start yr: 1993 $120,000
Community Energy Planning, Dept of Resources, Wild-life and Ec Dev, Energy Program Br, GNWT	All	Integrated approach to energy supply and demand Assistance to communities in carrying out integrated plans to implement measures to reduce energy demands and develop alternative energy forms Includes C&I and road transpo sectors In association with NWT Association of Municipalities	start yr: 1997 $40,000 Pilot project

2.3 UTILITY OR OTHER PRIVATE SECTOR INITIATIVES

Name & Source	Resid. Sectors	*Target* Approaches/tools	*Start year; 1996/7 expen.*
Insulation Program Phase 1, Hydro Québec	Existing low income & seniors	Insulation and weatherproofing (sealing) Evaluation of need/opportunities, and installation (pilot to cover 800 single family and 2700 duplexes or triplexes)	start yr: 1996 $ N/A Pilot was to run until end of 1997
Residential Efficient Water Heating -- Conservation Retrofits, Consumers Gas, Ontario	All existing	Reduced gas consumption for water heating Installation of low-flow water conservation devices at time of replacement of existing rental water heater or after "insufficient hot water" complaint	start yr: 1995 $540,000
Residential Energy Audits, Edmonton Power	Existing single family	Energy efficiency/conservation Low-cost residential audits, including electricity, water and natural gas	start yr: 1995 $10,000
Enviro Partners, TransAlta Utilities Corp, Alberta	All	Reduced energy costs Audits and retrofits for customers Program includes C&I sectors	start yr: 1996 $400,000
Home Improvements Program, BC Hydro	All	Reduced energy consumption and increased comfort Energy assessment service that identifies measures to improve efficiency of the home (draftproofing, windows & doors, ventilation, insulation, energy controls) Program includes attractive financing, payable over 5 years through hydro bills	start yr: 1990 $2.14 million Program slated to end in 1998
Boiler Efficiency & Testing Analysis, BC Gas Utility Ltd.	All multi-family, and new social housing	Boiler efficiency Assessment of and adjustment to commercial boilers to achieve maximum combustion efficiency; recommendations to improve operating performance	start yr: 1996 $ N/A Pilot/ demon-stration project
Energy Advisory/ Retrofit Program, BC Gas Utility Ltd.	All	Energy efficiency, combustion safety, IAQ Appraisal using computer diagnostics and air infiltration testing, plus implementation service to perform recommended upgrades Program includes loans component	start yr: 1996 $ N/A Program slated to end at end of 1997

2.4 NGO/NON-PROFIT SECTOR INITIATIVES

Name & Source	**Resid. Sectors**	***Target* Approaches/tools**	***Start year; 1996/7 expen.***
Home Audits/ Green Home Visits, Green Communities Organizations (GCOs), Ontario Martin – This is my addition. (I used this more general description in lieu of Consumer Gas entry "Green Community Audits")	All existing	Energy efficient houses and energy conserving behaviours Home visits by trained staff to assess options for increased efficiency e.g., insulation, weather-sealing, retrofits Private sector partners (e.g., utilities, financial orgs, equipment suppliers) sponsor specific services and/or provide energy-saving devices at cost Green home visits (GHVs) are a core service of most GCOs and are offered in over a dozen communities in Ontario. The concept is being adopted across Canada with assistance from the Green Communities Association	start yr: N/A $: N/A

3. FINANCIAL SUPPORT/INCENTIVES

3.1 PROVINCIAL/TERRITORIAL GOVERNMENT INITIATIVES

Name & Source	**Resid. Sectors**	**Target Approaches/tools**	**Start year; 1996/7 expen.**
Utility Manage-ment Program, Dept of Resources, Wildlife and Ec Dev, Energy Pro-gram Br, GNWT	All public housing	Reduced electricity consumption Replacement of electric hot water heaters with oil-fired, and replacement of old refrigerators with energy efficient models	start yr: 1997 $1.7 million Program slated to end in 1999

3.2 UTILITY OR OTHER PRIVATE SECTOR INITIATIVES

Name & Source	**Resid. Sectors**	**Target Approaches/tools**	**Start year; 1996/7 expen.**
Conservation and Electrical Improvement Loans, New Brunswick Power	All	Upgrading of insulation, windows, doors Low-interest loans Program also supports upgrading electrical systems	start yr: 1990 $210,000 Phased out in 1998
Consumption Rebate Program, Gaz Métropolitan, Montréal, Québec	All	Upgrading of natural gas equipment Discount on price of natural gas to help recover costs of replacement of existing with new, more efficient equipment	start yr: 1989 $N/A
Natural Gas Conversion Program, Gaz Métropolitan, Montréal, Québec	All	Natural gas conversion and efficiency improvements for central heating and water heating systems Financial assistance covering all or part of eligible expenditures to convert to natural gas systems or improve on existing natural gas systems	start yr: N/A $ N/A
PRC, Profigas Program, Gaz Métropolitan, Montréal, Québec	All	Natural gas installation or conversion Financial aid coupled with financing plan at advantageous rates for conversion or installation work Program includes all IC&I and transportation sectors	start yr: N/A $ N/A
Energy Studies Assistance Program, Gaz Métropolitan, Montréal, Québec	All	Energy efficiency of heating and air conditioning equipment Payment of up to 100% of costs of consulting engineer's analysis of consumption, performance, general conditions of equipment and recommendations Program includes all IC&I and transportation sectors	start yr: N/A $ N/A

Building Equip-ment Replacement, Centra Gas Ontario Inc.	Existing multi-family	Energy efficient equipment Information and grants/subsidies to owners & managers of small buildings who can cost-effectively replace existing with higher energy efficient equipment with-out engineering support; support to dealers to market efficient equipment Program includes C&I sector	start yr: 1997 $300,000 Program was only slated to run for 1997
Building Retrofit, Centra Gas Ontario Inc.	Existing multi-family	Gas-saving measures to implement during building renewal Optimized use of various delivery channels to market and install a broad range of discretionary gas-saving measures Audits, demonstrations, workshops printed & audiovisual materials, displays, grants/subsidies Program includes C&I sector	start yr: 1997 $350,000 Program was only slated to run for 1997
Home Retrofit, Centra Gas Ontario Inc.	Existing low-income	Gas-saving measures to implement during home renovations Optimized use of various delivery channels to ensure that energy-efficient measures are included in home renovations Demonstrations, printed and audio-visual material, seminars, grants/subsidies	start yr: 1997 $500,000 Program was only slated to run for 1997
Apartment Boiler Analysis & Adjust-ment, Consumers Gas, Ontario	All multi-family (apart-ment)	Combustion efficiency of power burners in space- and water-heating boilers Incentive to cover one-third of cost of analysing and adjusting burner	start yr: 1995 $14,000
Apartment Efficient Space & Water Heating Demon-stration, Consumers Gas, Ontario	Existing multi-family (apart-ment)	Increased penetration of higher efficiency commercial gas-fired space and water heating Incentive rental rates Program includes C&I sector	start yr: 1995 $28,000 Demonstration program
Custom Energy Efficiency Improve-ments for Large Volume Customers, Consumers Gas, Ontario	All multi-family (apart-ment)	Energy efficiency in large volume markets Promoting performance contracting Developing custom financing options Advertising, demonstrations, displays, seminars Program includes IC&I sectors	start yr: 1995 $52,000
Residential Efficient Space Heating, Consumers Gas, Ontario	All	Increased proportion of high-efficiency to mid-efficiency heating systems Financial incentives to customer and sales dealer, along with advertising/ information programs to customer	start yr: 1995 $95,000
Residential Space Heating Conservation – Retrofits, Consumers Gas, Ontario	All existing	Energy efficient houses (lower heat loss) Application of incentive finance rates to company's existing Home Improvement Program to promote envelope energy efficiency e.g., low-e windows	start yr: 1995 $108,000

Ground Source Heat Pumps, West Kootenay Power	All	Uptake of ground source heat pumps Grants or loans provided for qualifying buildings Program includes promotion via advertising, displays, printed materials, etc. Program includes evaluation component	start yr: 1992 $118,000 Program slated to end in 1998
HomeGuard, West Kootenay Power	All existing, seniors	Efficient use of electricity Program provides energy audits, insulation upgrades, other free products, and loans of up to $5000 for qualifying homeowners	start yr: 1989 $176,000 Program slated to end in 1998
Efficient Boiler Program, BC Gas Utility Ltd.	All multi-family, new social housing	Increased sale of mid- and high-efficiency boilers (market transformation) Grants/subsidies for qualifying installations (as demonstrations) Education and training for contractors, engineers, utility sales personnel, customers	Start yr: 1995 Program was slated to end at end of 1997
High Efficiency Furnace Program BC Gas Utility Ltd.	All	Appropriate home heating systems Assistance to customers in designing and selecting appropriate heating system $100 cash rebate or preferential financing to customers whose homes meet minimum heat loss criteria	Start yr: 1996 Program was slated to end at end of 1997

4. REGULATIONS/STANDARDS/CODES

4.1 FEDERAL GOVERNMENT INITIATIVES

Name & Source	**Resid. Sectors**	**Target Approaches/tools**	**Start year; 1996/7 expen.**
Model National Energy Codes for Buildings and Houses Energy Efficiency Branch, NRCan	All	Energy efficiency of residential buildings Specified minimum requirements, for adoption and implementation by relevant authorities at provincial/territorial and municipal levels	start yr: 1992 $700,000
R-2000 Home Program Energy Efficiency Branch, NRCan	All new	Energy efficiency of residential buildings Voluntary technical standard exceeding conventional codes for energy efficiency Licencing of R-2000 builders Promotional initiatives Standard also addresses environmental responsibility and indoor air quality	start yr: 1982 $830,000

Equipment Energy Performance Regulations Energy Efficiency Branch, NRCan	All	Energy efficiency of equipment Legislated minimum energy efficiency performance levels (by regulation under Energy Efficiency Act) Program includes IC&I sectors	start yr: 1992 $1.3 million

4.2 PROVINCIAL/TERRITORIAL GOVERNMENT INITIATIVES

Name & Source	**Resid. Sectors**	***Target*** **Approaches/tools**	***Start year; 1996/7 expen.***
Energy-Efficient Appliances Act Nova Scotia Dept. Natural Resources, Energy Utilization	All	Energy efficiency of appliances Legislated minimum efficiency levels for energy-using appliances and equipment sold or leased in the province (by regulation under the Energy-Efficient Appliances Act) Program includes equipment used in IC&I sectors	start yr: 1991 $12,000
Provincial Energy Efficiency Reg'n New Brunswick Natural Resources and Energy, Minerals and Energy Div'n	All	Energy efficiency of equipment Legislated minimum efficiency levels (by regulation under Energy Efficiency Act), based on national standards Program includes equipment used in C&I sectors	start yr: 1995 $25,000
Building Reg'ns Québec Ministère des ressources naturelles, Direction de l' efficacité énergétique Martin – Most provs must include some EE stuff in their Building Codes. Do we leave this one in?	All new	Energy efficiency of residential buildings Energy efficiency standards for new buildings Changes to standards as incorporated in the Loi et Règlement commentés sur l'économie de l'énergie	start yr: N/A $ N/A
Energy Efficiency Regs for Hydrocarbon- or Electricity-Powered Appliances Québec Ministère des ressources naturelles, Direction de l' efficacité énergétique	All	Energy efficiency of appliances Legislated minimum efficiency standards for frequently used appliances Program includes C&I sectors	start yr: 1992 $25,000

Energy Efficiency Act and Regulations Ontario Ministry of Environment and Energy, Industry Conservation Branch	All	Energy efficiency of appliances Legislated minimum efficiency levels (via development of consensus performance standards developed by standards-writing organizations) Program includes IC&I sectors	start yr: 1988 $195,000
Manitoba R-2000 Home Program, Manitoba Energy and Mines, Petroleum & Energy Service Br. Martin – Not clear how prov program relates to federal	All new	Energy efficient new home construction Voluntary technical standard exceeding conventional codes for energy efficiency Advisory services, audits, workshops promotional initiatives Standard also addresses environmental responsibility and indoor air quality	start yr: 1994 $125,000
Saskatchewan R-2000 Home Program, Sask. Energy Mines, Energy Development Branch Martin – as above	All new	Energy efficient new home construction; reduction of barriers to adoption of natural gas appliances As above	start yr: 1994 $ N/A

4.3 UTILITY OR OTHER PRIVATE SECTOR INITIATIVES

Name & Source	**Resid. Sectors**	***Target* Approaches/tools**	***Start year; 1996/7 expen.***
Residential Efficient Water Heating, Consumers Gas, Ontario	All	Increased energy efficiency of water heaters distributed through company's rental program Minimum efficiency level for water heaters purchased by company Promotion of higher efficiency heaters to customers	start yr: 1995 $1,000

APPENDIX B -- FEDERAL ENERGY EFFICIENCY ACT RESIDENTIAL EQUIPMENT STANDARDS

Equipment Type	Current Federal EE Act Standard	Proposed 4th Amendment	Future Proposed Standards	Current Canadian Stock Average(1)
Space Heating, Cooling, and Conditioning			Feds considering condensing gas standard	
Gas furnaces (min AFUE)	78%			66%
Oil Fired Furnaces (min SEUE)		78%		61% AFUE
Gas Fired Boilers (min AFUE)		Steam - 75% Hot Water - 80%		
Oil fired Boilers (min SEUE)		80%		
Ground- or water-source heat pumps (min COP)	C - 3.1 to 3.2 COP H - 2.5 to 3.0 COP			
Internal water-loop heat pumps	C - 10.0 EER H - 3.8 COP			
Single-package central air conditioners and heat pumps - Single Phase	C - 9.7 SEER H - 5.7 HSPF			
Single-package central air conditioners and heat pumps - Three Phase		C - 9.7 SEER H - 5.7 HSPF		
Split-system central air cond. and heat pumps - Single Phase	C - 9.0 SEER H - 5.9 HSPF	C - 10.0 SEER H - 5.9 HSPF	C - 12 SEER H - 6.6 HSPF	
Split-system central air cond. and heat pumps - Three Phase		C - 9.0 SEER H - 5.9 HSPF		
Room air conditioners (min EER)	8.0 to 9.0 EER			
Large Air Conditioners, Heat Pumps, and Condensing Units		8.3 to 12.9 EER 7.5 to 12.9 IPLV		
Gas Fireplaces			Feds Considering	
DHW Heating Equipment			Feds Cons. Increases US priority	
Electric water heaters (Max standby loss in watts)	71 to 200			
Gas water heaters (min EF)	43% to 58%			54% avg new units
Oil-fired water heaters (min EF)	50%			
Lighting				
Fluorescent lamp ballasts (min ballast efficacy factor)	.39 to 1.805		Feds Cons. Increases US priority	
General service fluorescent lamps (min lamp efficacy lm/W)	64 to 80			
General service incandescent reflector lamps (min lamp efficacy lm/W)	10.5 to 15		Feds planning stricter standard	

Equipment Type	Current Federal EE Act Standard	Proposed 4th Amendment	Future Proposed Standards	Current Canadian Stock Average (1)
Appliances				
Clothes dryers (min EF in kg/kWh)	1.36			1162 kWh/year 744 kwh/year new
Compact Clothes Dryers (min EF in kg/kWh)		1.31 to 1.42		
Clothes washers (min EF in L/kWh/cycle)	25.5 to 33.4		US - priority for increases	1195 kWh/year 1050 kwh/year new
Dishwashers - Standard (max kWh/year)	700			1048 kWh/year 700 kwh/year new
Electric ranges (max kWh/year)	408 to 516			680 kwh/year avg new
Gas ranges	No Cont Pilot			
Integrated over/under washer-dryers (min EF in kg/kWh dryers, L/kWh/cycle washers)	1.36 Dryers 25.5 to 33.4 Washers			
Refrigerators and combination refrigerator-freezers	various		New US Standard - 25% below current Canadian, July 2001	1223 kWh/year 660 kwh/year avg new
Freezers (max kWh/year)	730 to 1164			824 kWh/year 370 kWh/year avg new
Automatic Ice Makers (		various		
Other				
Electric motors from 1 to 200 horsepower (min efficiency)	70% to 92%			
Distribution and Dry -Type Transformers (max loss, Watts)		100 to 70,000	US - priority for increases	
Residential Dehumidifiers (min Energy Factor in L/kWh)		1.0		
Windows			Feds Considering	

(1) Numbers from Natural Resources Canada, Energy Efficiency Trends in Canada 1990 to 1996, June 1998